PAPERS AND PROCEEDINGS OF

# THE ROYAL SOCIETY OF TASMANIA

Edited by M. R. Banks and S. J. Smith

and Published by the Society

Hobart

Tasmania

31 AUGUST 1997

VOLUME 131

Museum of Victoria
44000

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MUSEUM OF VICTORIA LIBRARY

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VOLUME 131

## COUNCIL AND OFFICE BEARERS

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His Excellency the Governor of Tasmania
the Honourable Sir Guy Green AC, KBE

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# PAPERS AND PROCEEDINGS OF THE ROYAL SOCIETY OF TASMANIA
## VOLUME 131

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*Publication of this volume was generously supported by the Government of Tasmania and the University of Tasmania.*

# ROYAL SOCIETY OF TASMANIA
## Annual Report for the Year 1996

The Council has the honour to present to members the following report on the activities of the Society during the year.

## Council and Office Bearers

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## President

His Excellency Sir Guy Green took the Chair as President of the Society at the Annual General Meeting of the Society and at that of the Northern Branch. He presented the Royal Society of Tasmania Medal and the Clive Lord Memorial Medal at the Annual General Meeting and chaired the meetings at which the medal addresses were delivered. Lady Green accompanied him to hear the Clive Lord Memorial Medal Address.

Sir Guy Green, as President, presented the initial Royal Society of Tasmania Bursary to Ms Rose Andrew, International Biology Olympian, at Government House on 14 June.

## Bereavements

Mr A.W.G. Powell died on 21 January. During his 65 years as a member he made distinct contributions to the Society and published a number of papers in the Society's journal.

Mr John Tomlinson AO ( member since 1981) died on 23 November. Mr Tomlinson, a chartered accountant, was prominent in Hobart business circles. He freely contributed his expertise and wisdom to many boards and committees in Tasmania and more widely in Australia. For many years he was the nominee of the Royal Society on the Board of the Royal Tasmanian Botanical Gardens.

Mr A.H. Nightingale (member since 1963) died on 2 February.

## Honours and Awards to Members

Mr Alan Blow QC was awarded the Medal of the Order of Australia in the Australia Day Honours List for services to the arts, particularly through the Tasmanian Museum and Art Gallery (Chairman of Trustees) and the Salamanca Arts Centre Inc.

Tom and Cynthia Dunbabin of "Bangor", Dunalley, won a National Landcare Award in March for demonstrated excellence in tackling land and water-degradation problems. They discussed some of the measures they had taken at "Bangor" with members of the Society during an excursion to their property a few days later.

The Queen's Birthday Honours List recorded the award of the Medal of the Order of Australia to Dr Peter

McCartney for services to medicine, particularly as Director of Hyperbaric and Diving Medicine at the Royal Hobart Hospital. Dr McCartney, who conducted a Society visit to the hyperbaric unit in November 1994, has been a member of the Council of the Society, and a Vice-President.

## Membership

The membership is 403, a decrease of 45 relative to 1995 and is made up as follows:

| | |
|---|---|
| President | 1 |
| Honorary Members | 7 (2) |
| Life Members | 30 (9) |
| Ordinary Members | |
| receiving P. & P. | 240 (37) |
| not receiving P. & P. | 104 (37) |
| Associate Members | 21 (7) |
| TOTAL | 403 (92) |

Figures in brackets are those for the Northern Branch.

During 1996 the Society tightened up the rule on outstanding subscriptions with the result that, after due notice, the names of a number of members were removed from the Membership Roll.

Later in the year, a recruitment campaign based on a new Information Brochure resulted in more nominations for membership being received than usual. A streamlined procedure for election of new members was adopted during the year.

## Staff

Ms Vicki Farmery provided administrative and secretarial services to the Society during 1996. The thanks of the Society are extended to her.

## Volunteers

The group of volunteers (Mr G.D. Brown, Mr R. Lord, Mrs J. Parrott and Dr I. Skira) continued checking information on the Society's art collection in 1996 and were able to bring the work to the point at which problem areas could be clearly identified. Information is now being sought to allow resolution of the problems.

As the Society's files had not been scrutinised for several years for items for disposal or transfer to archives, a volunteer was sought to make an initial survey. The volunteer, Dr Bob Ellis, completed the survey, and appropriate disposal of the files is now in progress.

Council thanks these volunteers whose contributions are greatly appreciated.

## Council Meetings

There were four Council Meetings during the year. Matters which were of particular concern to Council included the progress of the Foundation, the new Royal Society Lecture Theatre and other facilities in the Custom House, membership, Society awards, the site of the Royal Society Library and bursaries for outstanding Tasmanian students. The Executive Committee met four times and made recommendations to Council.

## The Royal Society of Tasmania Foundation

The Foundation met twice during the year to review progress and to pursue matters of sponsorship, bequests and tax deductibility. During the year, donations by members, sales of books and sponsorships increased the balance in the Foundation to $35 097 at the end of the year. The subsequent auction of duplicates of Society books by Christie's yielded over $11 000, but the proceeds had not been received by 31 December.

## New Society Facilities

Negotiations with the Trustees of the Tasmanian Museum and Art Gallery about the use of Society facilities and equipment are in progress.

## Honours and the Honours Committee

At the Annual General Meeting of the Society in March the Royal Society of Tasmania Medal was presented to Professor Patrick Quilty and the Clive Lord Memorial Medal to Dr Alison Alexander. Professor Quilty delivered his Medal Address entitled "Antarctic research: its importance on the global context" at the May meeting and Dr Alexander her Memorial Medal Address on "Lady Hamilton in Tasmania: first-wave feminism in action" at the June meeting.

The Honours Committee (Dr S.W. Jeffrey [Convenor], Mr D.G. Hannan, Professor J.B. Reid, and Professor O.M. Roe) continued to consider nominations of future medallists and to examine the possibilities for institution of new awards.

## Grants to the Society

Council received support from the State Government in the form of a special grant of $3000 towards the cost of the Society's publication program and, through Arts Tasmania, a grant of $2000 towards the administration and promotion of the Society.

The publication program was also supported by a grant of $3000 from the University of Tasmania.

The Society acknowledges receipt of these grants with thanks and appreciates the support implied by them.

## Library

During the year, the integration of Royal Society Library records into the University database progressed. Most effort has been concentrated on the current serials and book collections. It is intended to house the Rare Books Collection with that of the University Library, and this Collection should all be reclassified and catalogued by the time this occurs.

A steady program of collection rearrangement to facilitate the reshelving of recatalogued/reclassified material, has been maintained. This has involved a significant amount of staff time and effort to allow for expansion of reclassified sequence

and compression of the older one. To assist with this process, new shelving was erected late in the year, at the expense of some reading space but without significantly affecting the layout of the library.

Volume 130, Part 1 of the Society's *Papers and Proceedings* was dispatched during the year using, for the first time, the Filemaker Pro program and one of the Library's Macintosh computers. This program allows for automatic label production and is easily maintained and updated to accommodate changes to addresses etc.

Binding of Royal Society serials continues to form part of the Morris Miller allocation, but the annual requirement has dropped, due to the Binder's acceptance of a larger volume size. Many volumes as now bound contain two bibliographic volumes instead of the previous one and, thus, only require binding every two years. This change in the arrangements is reflected in the decreased output, 34 volumes, for the year. Use of the Library and the Archives continues to improve, especially in the Archives, where a promotion program increased awareness of the resources available. Although the use of the Library is difficult to quantify, because of the problem of users failing to sign the register, there is no doubt that there is a steady increase, generated by the growing number of records appearing in the University Library database.

General housekeeping projects completed during the year include replacement of accessioning cards for current serials and new annotations for items which are to be displayed at the Museum. Several minor furniture rearrangements have occurred during the year, to facilitate reclassification and reshelving procedures together with displays and promotions of Library resources.

A systematic program to sensitise electronically (bug) all reclassified material was completed during the year and, henceforth, all catalogued/recatalogued items will be sensitised at the point of labelling and processing, although sensitising of large runs of recatalogued serials will continue to be undertaken by Royal Society Library staff rather than the End-processing unit.

Staffing of the Library has remained constant during the year with Graeme Rayner continuing as Royal Society Librarian. Carol Freeman continues to undertake the day-to-day duties required for the running of the Library, with assistance from Judy Jeffrey as and when required. Emilia Ward provides some time each day for assistance with special projects.

Statistics for the year follow: Consultations 45, Loans 79 (including 20 Interlibrary/Intercampus Loans), Visitors 172. The Consultation category is most likely to be significantly higher in reality and the Interlibrary/Intercampus category was only established as a separate count in November.

Significant changes in the physical arrangements of the University Library for 1997 are likely to affect the housing of the Society's Library, both in terms of its own location and the impact such moves will have on the day-to-day processing and subsequent output. The disruption should, however, result in greater access to and supervision of the collection with better housing of the Rare Books.

Council thanks Mr Graeme E. Rayner, Morris Miller Library, University of Tasmania, who was responsible for the Society Library during the year.

The University of Tasmania is planning a reorganisation of its library holdings and services. As the reorganisation will involve the Royal Society Library, Council has been holding discussions with the University on the future site of and services for the Society Library.

## Publications

Volume 130, Part 1, of the *Papers and Proceedings* was published in mid-July. In addition to the Annual Report for 1995, this part contains ten papers involving 15 authors from Tasmania and other parts of Australia. The papers deal mainly with Tasmania but include one on Macquarie Island and one on other areas in eastern Australia. The subject areas were botany, especially plant ecology, palaeobotany, glacial history, geology, geomorphology and zoology.

Late in December, Volume 130, Part 2, was published. This was a thematic volume, the theme being "Climate succession and glacial history of the Southern Hemisphere over the past five million years". Thirteen papers dealt with various aspects of the topic and were contributed by 30 authors from Tasmania, other parts of Australia and overseas. Part 2 was published in conjunction with the Tasmanian Division of ANZAAS, with the help of the Australian Antarctic Division and donations from the Australian Antarctic Foundation, and other organisations.

Mrs Alison Jones acted as sub-editor and Ms June Pongratz prepared the volume for publication. Their expert assistance is gratefully acknowledged.

Drs Max Banks and Mick Brown edited the volume.

## News Sheet

Short News Sheets were distributed to Members in March, May, July and September, the aim being to keep Members better informed of Society activities.

## Bursaries

Council decided for the first time to award bursaries to outstanding and rigorously selected Tasmanian Year 11 and 12 students representing Australia at international scientific events. The first was presented by the President at Government House on 14 June to Rose Andrew of Taroona and The Friends' School. She was a member of the Australian team at the International Biology Olympiad at Simferopol, the Ukraine, early in July. She won a bronze medal in the competitions.

A little later the Society awarded a bursary to Ashley Howlett of Howrah and Rosny College who represented Australia at the 1996 International Youth Science Forum in London late in July and early in August.

## Events in 1996

19 March (Annual General Meeting) — "Museums in the 21st Century: extinct or extant?" Ms Pat Sabine, Director, Tasmanian Museum and Art Gallery.

31 March — Excursion to "Bangor", Dunalley, led by Tom and Cynthia Dunbabin.

2 April — "Evolutionary trends in low-nutrient systems" Dr Tim Flannery, Australian Museum, Sydney; joint with the University of Tasmania.

7 May — "Antarctic research: its importance in the global context" Professor Pat Quilty, Royal Society of Tasmania Medallist.

4 June — "Lady Hamilton in Tasmania: first-wave feminism in action" Dr Alison Alexander, Clive Lord Memorial Medallist.

28 June — "Involvement of neurotrophins in activity-dependent neuronal plasticity" Professor Hans Thoenen, Max Planck Institute for Psychiatry, Germany; joint with the Medical School, University of Tasmania.

15 July — "The search for new technology in Australian Forestry" — a panel presentation led by Professor Jim Reid (The challenge facing eucalypt plantations) with contributions from Dr Nuno Borralho (Breeding for genetic improvement of eucalypts), Mr Robin Cromer (Improvement of soil and stand management practices in eucalypt plantations) and Dr John Madden (Protection of eucalypt plantations from vertebrate and invertebrate browsers).

6 August — "Do the eyes have it? The glaucoma inheritance study in Tasmania; the search for the genetic basis of glaucoma" Dr Paul McCartney, consultant ophthalmological surgeon.

3 September — " Redefining Australian society by design" Mr Michael Bryce, architect, planner and graphic designer, Brisbane (sponsored by QANTAS).

1 October — "Saving the 20th Century" Mr Barry McNeill, architect, planner and urban research consultant.

5 November — "Winter drought in Tasmania —I'd like to see that!" Dr Michael Pook, University of Tasmania and ABC.

3 December — Tour of Tom Roberts Exhibition, Tasmanian Museum and Art Gallery, led by Mr David Hanson, Curator of Art, and Ms Pat Sabine.

12 December — "Power surge protection" Dr Stephen Gumley, Global Lightning Technologies, followed by a tour of the works and a dinner at "4 XCELLENT FOOD", Technopark, Dowsings Point.

14 December — Members joined graduates of the Geology Department, University of Tasmania, on a cruise on the Derwent River in the *Cartela*, with geological and historical commentary by Dr Max Banks.

Attendance at functions ranged from 22 ( on the cruise) to about 175 ( at a joint meeting), with an average of 50. The program for the year was arranged by Dr John Thorne (Convener, Program Committee).

## Northern Branch

*Branch Council*

| | |
|---|---|
| Chairman | Professor Campbell Macknight |
| Vice-Chairman | Ms Judith Hollingsworth |
| Past-Chairman | Mr Elvin Fist |
| Honorary Secretary | Mr Chris Tassell |
| Honorary Treasurer | Mrs Doreen Girvan |
| Council Members | Mrs Christine Beswick |
| | Mrs Mary Cameron |
| | Mr Brian East |
| | Mr David Hannan |

The Council met five times during the year.

*75th Anniversary of the Northern Branch*

The Anniversary was marked by a Symposium at the Queen Victoria Museum on 13 July. Sixteen organisations and groups from northern Tasmania gathered to talk about their interests, activities and difficulties. The symposium was chaired by Professor Graeme Davison from Monash University.

*Meetings and Lectures*

23 February — "Reconstructing Tasmanian Past Glacial Climate" Mr David Hannan, University of Tasmania.

22 March — Annual General Meeting chaired by the President, His Excellency, Sir Guy Green, Governor of Tasmania; "Anthropology in Australia and its role in Museums" Professor John Mulvaney, Australian National University.

19 April — "Malacology in Tasmania: Past, Present and Future" Dr Brian Smith, Queen Victoria Museum and Art Gallery.

3 May — "The age of ecology: ecological thinking and our environmental history" Dr Dan Huon, University of Tasmania; joint with the Launceston Historical Society.

7 June — Members' Night

"Mining methods of Papua New Guinea" Mr John Carswell

"Ancient writing" Professor Campbell Macknight

"Pollution" Mr Bruce Pike.

2 August — "Transport Policy: Current Trends" Dr Coleman O'Flaherty.

6 September — "Mad Cow Disease" Dr Rod Oliver, Department of Primary Industry.

9 October — Panel presentation by students, University of Tasmania, Newnham.

"Bush Nursing in Tasmania" Ms Marita Bardenhagen

"Glacier in the Upper Meander Valley" Mr Michael Thrush

"The George Town Female Factory" Ms Dianne Phillips.

1 November — Members' Night

"Norfolk Island" Mrs Doreen Girvan

"Chasing Sixes around the World" Mr Ross Smith

*Excursions*

15 June — Northern Regional Library, demonstration of the Internet.

## Nominees to other Bodies

### Tasmanian Museum and Art Gallery

Council nominated Dr A.V. Brown and Professor J.B. Reid to serve on the Board of Trustees for 1996. Dr Brown arranged for Ms P. Sabine, Director, to report on the year's activities as follows:

Record attendances (151 000), a higher than usual monthly figure throughout the year and other events made 1996 a significant year for the TMAG.

The Custom House has been operating effectively and the Children's Discovery Centre and the Royal Society's Lecture Theatre have been in regular use. Progress has been made towards the establishment of a Cafe to open in April 1997. The regular program of tours by volunteer guides both to the general areas of the TMAG and to special

exhibitions has been very effective and well patronised.

With the substantial support of the Trust Bank Foundation and Dr John and Mrs Jill Freeman, major improvements in building infrastructure and the collection development have been achieved. These include the refurbishment of the upper Gallery of the 1863 building, now known as the Trust Bank Foundation Gallery, to its original Henry Hunter design. Further work continued on the upgrading of the Moonah Store and Dissecting Laboratory, the Private Secretary's residence, the 1966 Building stairwell and the staircase of the 1863 Henry Hunter Building. The staircase refurbishment was precipitated by the long-term loan from a private collection of a period chandelier.

With the financial support offered by the City of Hobart and the Art Foundation, Peter West has been employed as Marketing Services Consultant to improve the community profile of the TMAG and develop a sponsorship and public relations program.

The 1996 exhibition program was notable for its diversity. Major exhibitions included the following: *Mitey Science*, an interactive exhibition for 3 to 8 year olds, from the Investigator Science Centre attracted 15 000 children; *Eat, Drink and be Merry — entertaining at home 1840–1970* Decorative Arts from the TMAG Collections; *The Brett Whitely Retrospective* from the Art Gallery of New South Wales; *Mazda presents Tom Roberts as you've never seen him before* from Art Exhibitions, Australia; *Worth taking and keeping: a History of Tasmanian Photography 1848–1914* from Tasmanian collections; *Brushing* the *Dark* Contemporary Tasmanian responses to landscape; *Wool in the Australian Imagination* from the Historic Houses Trust of NSW; *Real Wild Child —a history of Australian Rock Music* from the Powerhouse; *Fashion Afoot* from the National Gallery of Australia and *National Glass Art Collection* from the City of Wagga Wagga.

School holiday programs and special events such as *Frog Week* drew large numbers of participants.

The research program continues with the Herbarium collecting flora for the AMRAD contract. Dr Kantvilas chaired the opening symposium "Lichens of High Mountains" at the 3rd International Association for Lichenology in Salzburg. He continued research at the British Museum of Natural History, the Royal Botanic Gardens, Edinburgh and the University of Graz. He led a group of 20 postgraduate students from Graz on a series of field trips in Tasmania.

Andrew Rozefelds was awarded an ANZAC Fellowship to establish contacts and collect material in support of his research into Southern Hemisphere floras, spending some weeks examining New Zealand collections and in the field.

Information Services Curator, Alison Melrose, has ensured a presence for the TMAG on the Internet through DECCD's Cultural Page. Computerisation of collection records continued with the assistance of volunteers and Jobskills staff. The assistance of volunteers has been vital but the TMAG would see significant benefits with an increase in the hours of presently employed, part-time professional staff, particularly in the area of Information Services, scientific preparation, conservation of works on paper and textiles and Assistant Curatorships in Art, History and Applied Science.

Considerable progress has been made over the last five years with physical infrastructure and public program development. The next five years should see major attention turned to the collection, especially in the area of long-term displays of the natural history collections, research and publications about the collections and fund-raising to ensure that collections can be adequately preserved and developed. The second stage of the ten-year redevelopment will begin in the 1997–98 financial year. The members of staff of the TMAG are to be commended for an excellent year's work and the Director, Patricia Sabine, has been contracted by DECCD for a further five-year term in her present position.

### Royal Tasmanian Botanical Gardens

Mr J.E. Tomlinson AO was nominated to serve on the Board of Trustees for 1996. Due to his death late in the year, a nomination for a replacement is being sought. The Society is grateful to Mr Jim Kane, RTBG, for the following report on the year's activities.

Considerable progress was achieved towards supporting the mission of the RTBG this year, including finalising the new corporate image and logo and publishing the RTBG mission statement. Other achievements included increased visitation levels, drafts of strategic action plans completed, the acquisition of significant grants and sponsorships, and funding and installation of several heritage-style solar lights. Many weeks were devoted by all staff towards developing a Draft Enterprise Development Agreement, which promotes a new approach to work and job design, incorporating the development of a performance management system and training career path based on a competency framework.

There has been substantial progress made on three major plant collections. Two grants from the Australian Antarctic Foundation were awarded, one of $18 000 to equip a refrigerated container, and one of $70 000 to build a prototype display house. This money has allowed the RTBG to make significant progress towards our vision of a substantial alpine and subantarctic plant display house. Generous sponsorship from Computerland and the Friends of the Royal Tasmanian Botanical Gardens has allowed us to begin work on the Chinese Section, which will consist of an interesting assortment of provenance, wild-collected plants from the Yunnan Province, collected by Mr Jim Cane.

One of the distinguishing features of botanical gardens is the management by scientific guidance and programs of scientific research. The goal of putting science into the RTBG programs was initiated in 1995 with the appointment of a Research and Documentation Manager, and, as a result, we have formed, with the University of Tasmania, the Southern Hemisphere Conifer Research and Conservation Centre. Several research projects have been initiated via this Centre, including Tasmania's conifer history and tissue culturing of rare and endangered conifers, and many co-operative links have been built.

Dr Leonie Scriven, the Research and Documentation Manager, is supervising a doctoral student at the University, has been awarded an Australian Research Grant, attended a scientific conference on the Proteaceae and presented a paper which will be published this year, contributed to two chapters in the *Flora of Australia* and had another paper published in an international scientific journal. Upgrading of the computer and science facilities, an initiation of a mapping program for the living collection and drafting of a living collection policy were also begun.

The most overwhelming problem for the RTBG during the year was the increase in the area known to be affected by plant diseases, namely *Phytophthora cinnamomi,* and *Armillaria luteobubalina.* Both diseases represent a major threat to the survival to the RTBG collections in their current form. The continuing loss of trees and shrubs, and the increase in size of the area known to be affected to one and a half hectares, has become of the greatest concern to the RTBG. More than 13 large trees have so far been lost and many others are known or believed to be affected. Via co-operative links with many organisations and individuals, local and abroad, the RTBG has been actively trying new techniques to assist with the problem. A public appeal for funds to help fight these diseases was strongly supported by the Tasmanian community.

## Acknowledgements

The Council is grateful for help generously given by many individuals and organisations. The lecturers, the Government of Tasmania, the University of Tasmania, Arts Tasmania, the Tasmanian Museum and Art Gallery and the Queen Victoria Museum and Art Gallery are particularly thanked for their support and cooperation.

Attention is drawn to the help received from Mr and Mrs T. Dunbabin of "Bangor", the Northern Regional Library and Global Lightning Technologies Pty Ltd during visits by members to facilities under their control. Council thanks these people and bodies for their help and hospitality.

Ronald T. Banks
Vice-President
4 February, 1997

M.R. Banks
Hon. Secretary

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## ROYAL SOCIETY OF TASMANIA

### Independent Audit Report

To the members of the Royal Society of Tasmania.

Scope
We have audited the attached accounts of the Royal Society of Tasmania for the year ended 31st December 1996. The Society's office bearers are responsible for the preparation and presentation of the accounts and the information they contain. We have conducted an independent audit account of these accounts in order to express an opinion of them to the members of the Society.

Our audit has been conducted in accordance with Australian Auditing Standards to provide reasonable assurances as to whether the accounts are free of material misstatement. Our procedures included examination, on a test basis, of evidence supporting the amounts and other disclosures in the accounts, and the evaluation of accounting policies and significant accounting estimates. These procedures have been undertaken to form an opinion as to whether, in all material respects, the accounts are presented fairly.

As detailed in Note 1 to the accounts, the Society is not a reporting entity because no users exist who are unable to command the preparation of reports tailored so as to satisfy specifically all of their information needs, and these Accounts are therefore "Special Purpose Financial Reports" that have been prepared solely to meet the requirements of the members of the Society.

Qualification
The Society's accounts for the year ended 30th June 1995, were not audited by this firm. The results of the Society for the year ended 30th June 1996 would be affected to the extent of any misstatement of financial information in the 30th June 1995 Financial Statements.

The audit opinion expressed in this report has been formed on the above basis.

Audit opinion
In our opinion, subject to the above qualification, the accounts of the Royal Society of Tasmania are properly drawn up so as to give a true and fair view of the Society's state of affairs as at 31st December 1996.

DELOITTE TOUCHE TOHMATSU

D.L. Wilson
Partner
Chartered Accountant

Date: 12th March 1997.

# ROYAL SOCIETY OF TASMANIA

## Statement for Royal Society Foundation
### Year ending 31 December 1996

Foundation approved by membership and Council 1995. Officially opened November 1995.

The Royal Society Foundation Trust Fund replaces all previous Trust and Memorial Funds.

Funds held by Perpetual Trustees (as managers)

| | |
|---|---|
| Funds held at 31 December 1995 | $23 134.10 |
| Capital deposits during 1996 | 9 270.00 |
| Total capital at 31 December 1996 | $32 404.10 |
| Interest: | |
| Interest derived from capital fund | 2 639.35 |
| Interest derived on interest fund | 54.24 |
| Total funds in Trust at 31 December 1996 | $35 097.69 |
| Other information: | |
| Funds transferred in January 1997 | 2 148.00 |
| Sales profit of rare books deposited January 97 | 11 620.00 |
| Estimated value of Trust at date of AGM | $50 000.00 |

## Accumulation Account
### for Period 1 January–31 December 1996

| | |
|---|---|
| Balance at 1 January 1996 | $ 60 051.30 |
| Balance adjusted for uncashed cheque ($44.00) | 60 095.30 |
| Cash items: | |
| Add increases at bank | -5 410.65 |
| Subtotal at 31 December 1996 | 54 684.65 |
| Asset items: | |
| Add new assets as per statement of payments | 2 338.00 |
| New total for 1996 | $57 022.65 |

## Royal Society of Tasmania — Northern Branch
### Statement of Receipts and Payments
### Year ending 31 December 1996

| | | |
|---|---|---|
| Balance at 1 Jan 1996 | | $64.55 |
| Receipts | | |
| Subscriptions | 210.00 | |
| Grant | 1 920.00 | |
| Bank interest | 8.10 | 2 128.10 |
| | | $2 192.65 |
| Expenditure | | |
| Subscriptions to RST (Hobart) | 210.00 | |
| Printing and stationery | 77.20 | |
| Postage | 388.35 | |
| Post box | 40.00 | |
| Secretarial | 845.00 | |
| Bank charges | 4.95 | |
| Suppers | 113.50 | |
| Travelling | 219.00 | |
| Miscellaneous | 210.00 | $2 108.00 |
| Bank balance 31 Dec 1996 | 114.65 | |
| Less unpresented cheque (361) | 30.00 | 84.65 |
| | | $2 192.65 |

## Statement of Receipts and Payments
### Year ending 31 December 1996

| | | | | |
|---|---|---|---|---|
| *Balance – 1 January 1996 (as audited for 1995)* | | | | 40 134.07 |
| Balance adjusted for 'dead' cheque | | | | 44.00 |
| | | | Revised total | $40 178.07 |
| *Add receipts* | | | | |
| Subscriptions | | | 11 998.00 | |
| Publications | regular sales | 2 031.95 | | |
| | rare book sale | 1 550.00 | | |
| | ANZAAS related | 7 535.00 | 11 116.95 | |
| Donations | per symposia | 1 350.00 | | |
| | to Foundation | 1 673.00 | 3 023.00 | |
| Interest | | | 971.79 | |
| Government grant | | | 5 000.00 | |
| Meeting funds (var functions) | | 5 111.20 | | |
| | room hire | 628.80 | 5 740.00 | |
| | | | add | 37 849.74 |
| *Deduct payments* | | | | |
| Subscriptions | | | 3 618.11 | |
| Printing & stationery | | | 2 336.00 | |
| Postal costs | | | 2 223.05 | |
| Meetings Attendant's fees | | | 1 124.10 | |
| Functions | | | 2 796.85 | |
| Bank charges | | | 95.82 | |
| Publication costs | | | 10 968.43 | |
| Northern Branch | | | 1 910.00 | |
| Secretarial services | | | 3 360.00 | |
| Administration/insurances | | | 798.45 | |
| Sundries Repairs | | 100.00 | | |
| Book removal costs | | 369.00 | 469.00 | |
| Student support | | | 700.00 | |
| Foundation/society advertising/promotion | | | 2 020.58 | |
| funds transfer | | | 8 410.00 | |
| | | | less | 43 260.39 |
| *Balance – 31 December 1996* | | | | $34 767.42 |
| Bank reconciliation: | | | | |
| Uncashed payments 1996 | | 372.00 | | 372.00 |
| | | | | $35 139.42 |
| At bank: | | 35 135.42 | | |
| Cash in hand: | | 4.00 | | |
| | | | | $35 139.42 |

## Royal Society of Tasmania — Northern Branch
### Reconciliation Statement 1996

| | | | |
|---|---|---|---|
| Credit balance as per bank statement 31 Dec 96 | | 114.65 | |
| Less unpresented cheque (699361) | | 30.00 | $84.65 |
| Credit balance at 1 Jan 1996 | 64.55 | | |
| Receipts for year | 2128.10 | 2192.65 | |
| Expenditure for year | | 2108.00 | |
| Debit balance | | | $84.65 |

Clive Lord Memorial Lecture

# TERESA HAMILTON IN TASMANIA: FIRST-WAVE FEMINISM IN ACTION

by Alison Alexander

(with one plate)

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Teresa Hamilton arrived in Tasmania in March 1887, when her husband, Sir Robert Hamilton, became Governor. She undertook the social activities expected of the governor's wife with panache but, being a forceful lady, she was imbued with new ideas of the activities suitable for women, such as were becoming popular in Britain. She arranged, sometimes even delivering herself, lectures on health, diet, sanitation, first aid, nursing and hygiene, open to women of all classes. She formed the Nursing Band which later became the District Nursing Association and involved herself in a women's refuge home, education for girls, sanitary reform and temperance activity. Other interests were women's sport, art and the still-existing Hamilton Literary Society. In two areas she encouraged women to influence public opinion and try to change laws. Teresa Hamilton left Tasmania with its structure much as it had been before her arrival, but with women of all classes shown how to play a more active role in that structure.

**Key Words: Teresa Hamilton, governors' wives, feminism, health, sanitation, nursing, hygeine, literary society, Tasmania.**

Sir Robert Hamilton was governor of Tasmania from 1887 to 1892. His entry in the *Australian Dictionary of Biography* describes his various activities, none of which appears to have exceeded the call of duty, and comments that his greatest contribution in Tasmania was to the colony's cultural life. In fact he did little for the colony's cultural life; the contribution came mainly from his wife Teresa. The *Dictionary* entry, however, only mentions her as founding a literary society, in reality one of her lesser activities.[1] This paper aims to give a more accurate assessment of her achievements.

The position of 19th-century Tasmanian governor's wife consisted very much of what the incumbent wanted to make of it. A governor's wife could remain in the background, running her family and holding occasional social gatherings, but there was room for considerable activity if she desired it, as several did.

In the first 20 years of settlement, the colony was a small, rough place, where notions of respectable behaviour had little force, and people were remarkably free to do what they wished. Governors had wives and mistresses, and these women undertook such activities as running a farm or a shop, selling meat to the government, having love affairs and even being the cause of a duel. Several had dubious backgrounds, which in England would have meant social ostracism, but in Tasmania were little noticed.[2]

With the arrival of the Arthurs in 1824, this atmosphere began to change. Arthur tried to improve society's morals, and his wife was a suitable spouse for such a man: devoted to her large family, a model of respectable behaviour, and an apparently uncomplaining hostess for Arthur at weekly dinners and many other entertainments, such as balls. She also acted as her husband's secretary, copying out letters for him, and did some charitable work.[3]

The next governor's wife, Jane Franklin, tried to broaden women's interests. This was somewhat resented by various colonists. She also assisted her husband in government, which was strongly resented, for a woman was seen to have no place in politics. Jane Franklin's activities show the limits of the role of governor's wife.[4]

With Caroline Denison came another perfect example of the Victorian woman. Like Eliza Arthur, she cared for her large family; supported her unpopular husband, though always a step in the rear; ornamented social occasions and held many balls and dinners; and was no threat to male domination. She did a considerable amount of charitable work and established the Van Diemen's Land Asylum to rescue prostitutes, but this lasted only five years. She was also active on several committees, such as that of the Dorcas Society, which assisted poor married women in childbirth. Bishop Nixon commented that it would be long before the colony would have Caroline Denison's equal as "head of our female society — exhibiting, as she does, a bright pattern of all that is good and gentle, ladylike, and amiable".[5]

"Head of our female society" could indicate merely a social role, but it did imply room for more activity, if the woman wished it. For the next 30 years, governors' wives more or less followed Caroline Denison's example. Augusta Young was a lavish hostess in Government House. She was known for her "active benevolence" and attended meetings of the Dorcas Society. Though not assertive, she did once give a "very nice little speech".[6] She was followed by Mrs Gore-Brown, also a charitable woman. Quiet, unostentatious and devoted, she assisted the Dorcas Society, the Benevolent Society and the Ragged School. She established the Female Refuge for prostitutes; this became the Girls' Industrial School, which assisted poor girls by training them as domestic servants. The School was run by a committee of 20 hard-working Protestant ladies, who included Mrs Gore-Browne. She was also reported to have done "much to refine society" in Hobart.[7]

The next governors' ladies, Mrs Du Cane and Mrs Weld, also assisted the Dorcas Society and the Girls' Industrial School, though Louisa Meredith wrote that Mrs Du Cane's sole eminence lay in "a taste for bull-dogs and loud talking".[8] Lady Lefroy, too, supported these charities, and established the Female Refuge at Risdon in 1881. This aimed to rescue prostitutes but had a shorter life than even Caroline Denison's establishment, ceasing to exist in 1882.[9] Rescuing prostitutes was a popular cure-all for the woes of society at this time; the women would be saved from a life of sin and, without their services, there would not be the opportunity for men to indulge in vice. In Tasmania, such charities were not particularly successful, however, partly from a

lack of support by the respectable population and partly from a lack of desire by prostitutes to be saved.

The next governor, Strahan, was a widower, so there was no chatelaine at Government House.[10] In 1887, Tasmanians prepared to welcome another governor's wife, Teresa Hamilton.

By mid-century, the Victorian ideal of womanhood had taken a strong hold in Britain: that women's place was in the home, running the domestic side of life and bringing up children. If women wanted to do more, they could undertake social or charitable activity, but that was all. They had no place in business, in politics, in higher education and intellectual activity, in the general world outside the home, which was men's domain. It was thought that their natures suited them for this role, that they were not strong enough for the hurly-burly of the outside world. They should not have outside employment: of course, some needed to support themselves, and many working-class women were forced into paid employment but, ideally, they would be supported by a male — father, husband, son or even uncle — and would not need to soil their hands by paid work. One of a man's aims in life was seen as earning enough to keep his womenfolk in ladylike idleness.

From the 1840s, there were stirrings of rebellion by women against this domestic role. Small groups began to work for women's suffrage, and some individuals like Florence Nightingale, who wanted to do more with their lives than sit at home, carved out careers for themselves, though with great difficulty and against strong male opposition. From the 1870s, schools were founded which gave girls a full secondary education. The rights of women began to be a topic of conversation and, even in Tasmania, this term was known, for the Tasmanian *Punch* published a joke about it. Moreover, in 1875, one modern girls' school was founded, the Hobart Ladies' College.

For years in Britain, there were only small gains by women, but then, in the mid 1880s, there was a flowering of activity, for reasons still debated. What this meant was that there was suddenly far more activity outside the home by women. This came as women formed groups and undertook activities in areas like charity, sport, church and intellectual pursuits; as more secondary schools for girls were established; as women demanded tertiary education; as professions opened to women, and women's general career opportunities expanded dramatically; and as women demanded the vote.

There were some signs of the British activity being duplicated in Tasmania, mainly in the establishment of schools which provided secondary education for girls, particularly the Methodist Ladies' College, Launceston (1886), The Friends' School, Hobart (1887), and the Presbyterian Ladies' College in Hobart (1888) — all founded by religious groups. Nevertheless, by the time of Teresa Hamilton's arrival in 1887, there had been little major change in women's position generally; there were few societies which admitted women, they seldom appeared in newspapers, and most confined their interests to domestic activity. There was certainly no woman who advocated any idea of women's rights.

Teresa Hamilton was, unusually for a 19th-century governor's wife in Australia, of Australian background herself. She was born in 1852, and her father, Major Henry Reynolds of the 58th Regiment, died when she was seven. Her mother was born Ann Cox, distantly related to the Tasmanian Cox family of Clarendon and the sister of Lady Youl of Simmons Plains. Despite these Australian relations, Teresa Reynolds had no convict connections. Her Cox grandfather and later the Reynolds family lived at "Hobartville", Richmond, New South Wales; from her later career, one can presume that Teresa received a good education, and in 1877, aged 25, she married Robert Hamilton.[11]

By this time Hamilton was 40. He was the son of a Scottish clergyman and had joined the public service, becoming accountant to the Board of Trade and secretary to the Admiralty. He had been married before, but his first wife died in childbirth, after presenting him with five sons and a daughter. The daughter, Anne, later wrote her autobiography[12] and, amazingly, never once mentioned her stepmother, merely noting that her father remarried 18 months after the death of his first wife. The children, who had learnt at home with governesses, were then sent to boarding school. Teresa Hamilton bore her husband two further children, a son and a daughter. Well-educated and forceful, she was imbued with new ideas of the activities suitable for women.[13]

Several years after their marriage, Hamilton was made secretary to the Irish administration, a position left vacant by the assassination of two previous officials in a Dublin park. The move to Dublin cannot have been easy for a family with young children. Despite the assassination, Hamilton became tainted by sympathy for Irish home rule, so he was removed from this position and instead, at the age of 50, was made Governor of Tasmania (his wife was then 35). The Hobart *Mercury* did not think the new position a demotion, but said that Sir Robert should be glad to change "an onerous, troublesome and thankless post" for "the dignified and honourable position of Governor of this fair dependency of Her Majesty's Crown".[14]

Sir Robert's term of office was not distinguished by any special activity, and he would persist in calling the premier the Prime Minister, but he promoted public works and the investment of British capital in the colony, though to what extent is unknown. He was president of the Royal Society (an activity which, according to his daughter, he enjoyed)[15], supported the Australasian Association for the Advancement of Science, organised celebrations for Queen Victoria's Diamond Jubilee in 1887, and opened a number of museums and art galleries, as he was paid to do. A more unusual activity for a governor was opening a congress of trade unions. Hamilton seems a quiet, pleasant figure — he was seldom mentioned, for good or ill, in the Walker letters (see below) — and was described as "an able and industrious public servant".[16] He much enjoyed pottering in the gardens of Government House, clipping the hedges and lying in a hammock.[17]

Inside information about the Hamiltons comes from three sources. In 1966, Agnes Morris wrote a small book, *Lady Hamilton's Tasmania*, which gives a glowing account of the period. Agnes Morris' granddaughter commented that her grandmother only liked to see good in people; that, in fact, you only see the good, if you keep your eyes shut.[18] So Morris depicted Lady Hamilton as able, charming and inspiring, for example writing that when she married Hamilton, the children of the first wife had a better life in her "kind, capable hands".[19]

In 1889, showing the growing visibility of women in the community, the *Tasmanian Mail* introduced a weekly women's column, written by "Alix". Alix often recorded

Lady Hamilton's activities and approved of them on the whole, so this is another positive view.

A more critical opinion comes in the letters of Sarah and James Walker to their sister Mary, who was studying art in London. Well-educated, intelligent, interested in intellectual matters as well as social events, and both busy with employment — James as a lawyer and Sarah as a teacher — they appreciated Teresa Hamilton's achievements but could also see her defects, and felt free to point them out in their private letters. Proud of their Tasmanian heritage, they were not inclined to kowtow to British imports, however elevated their position. James Walker illustrated this when he described the Mault family as "terrible conservatives and worshippers of the aristocracy ... which I am not".[20]

There are several descriptions of Teresa Hamilton's appearance. At a reception, she was described as looking "very handsome in a pale tan armure frock, with tints of white moire softening it in a marvellous way, and a tiny fawn bonnet, while her face is so good, so true, one cannot help instinctively admiring the nobility of character speaking through it".[21]

James Walker was less flattering when he described her portrait, by well-known artist Tennyson Cole. Cole's subjects included Edward VII, but Walker was not impressed with his portrait of Teresa Hamilton. The drapery was well painted, he said, "but he made her face florid & fat & reddened the complexion, while as to her hair, which is Teresa's chief beauty, he had taken all the light & colour out of it & made it a sort of dirty brown". Cole was similarly unsuccessful with Sir Robert, whose portrait looked "uglier than the reality".[22] (This is the one comment about Sir Robert in the Walker letters.)

The Hamilton entourage arrived in Hobart in March 1887, sailing up the Derwent on a perfect day. They were "accorded a hearty and enthusiastic welcome" by "people of all degrees and all classes", over a thousand assembling to cheer them as they landed. "The winning grace of Lady Hamilton's manner at once instilled her as a popular Governor's lady".[23] It was decided to conduct the official swearing-in that day, so there was a great bustle as the streets were cleaned. "All the sweeping and flushing, however, could not remove an olfactory demonstration of the fact that our system of drainage is one of those things that it is perhaps possible to improve upon," an ominous portent. Crowds gathered in the streets, flags were hung and arches erected, and at three o'clock the vice-regal carriage appeared. Teresa Hamilton had "gracefully adorned" her bonnet with a bunch of Tasmanian mountain berries, a tactful touch, and the Mayoress presented her with a magnificent bunch of these same berries. A procession formed and marched through the Hobart streets, church bells rang, people cheered, bands played, and the whole enterprise went off most successfully. The only slight disorder was the action of a "gentleman who had imbibed sufficient refreshment to make him argumentative", but a constable easily quelled him.

The swearing-in took place in the Supreme Court. It was the first time that ladies had been admitted, and a number sat on the dais. Addresses of loyalty were also read from various sections of society, then, amid more cheers, the vice-regal party drove back to Government House. It was a propitious start to their regime.[24]

When Teresa Hamilton left Tasmania, Alix commented that she had had a difficult task, for before her arrival there had been no governor's wife, or they had been so taken up with the cares of large families that they had not spent much time on the public good. During the time of widower Strahan, "kind and good-natured man," general matters at Government House had become very disorganised, and Teresa Hamilton had to set things right.[25]

*PLATE 1*
*"Portrait of Lady Hamilton" by Philip Tennyson Cole, 1809. Collection: Tasmanian Museum and Art Gallery.*

It appears that she did this without undue difficulty, for she was an excellent organiser and undertook the social activities of the governor's wife with panache, holding At Homes, balls, receptions, dinners, evenings, dances and afternoon teas.[26] Possibly, however, there were difficulties at first. Sarah Walker quite frequently attended entertainments at Government House, and in 1890 wrote that "we had to go out to Government House yesterday afternoon ...There were a good many people there. Lady H. is a much better hostess than she used to be, I think ... She is very amiable to me lately".[27] There were also such entertainments as a grand Charity Ball, organised by a committee of prominent women, including Teresa Hamilton. At this, she wore a handsome dress of grey silk, trimmed with grey velvet.[28]

Then there were the many official functions which the Governor and Lady Hamilton attended, such as a Review on the Queen's Birthday, and many ordinary social events which the vice-regal party graced: the races, polo matches, the theatre.[29] One of Teresa Hamilton's earliest activities was "a very pleasant one indeed": she telegraphed to Queen Victoria a congratulatory address, signed by 23 000 Tasmanian women, on the occasion of her jubilee.[30] She then held a dazzling Jubilee Ball at Government House.[31]

Another activity expected of vice-regal couples was travelling round the colony, and Sir Robert and Lady Hamilton did this enthusiastically. Within a fortnight of

their arrival, they went to Launceston and the northwest coast and, during the following years, they often travelled, with Teresa Hamilton particularly interested in visiting her relations, her first cousins the Youls and her more distant cousins, the Coxes.[32]

There was far more to the new governor's wife than these expected social activities, however. Shortly after Teresa Hamilton arrived in the colony, in September 1887, she delivered an address to the women of the colony, on the topic "Sanitation and Public Health".[33] "To speak in public for the sake of speaking is not my habit", she said, but she would not be doing her duty as the wife of the Governor if she did not help him improve the colony's health. Their son had had typhoid, and nursing him inspired her to act. She urged women to co-operate with her and learn to nurse intelligently and help stop typhoid spreading. "The situation cries for reform." People must appeal to the City Council to act, and to builders of houses. Mothers should burn all impurities, ventilate rooms, and clean stagnant gutters in front of houses. Apparently there was no further action after this lecture was given, and Alix put this down to Tasmanian apathy.

Teresa Hamilton had more success in later years.[34] The St John's Ambulance Brigade was established in Hobart in 1887, and from 1889, at the instigation of Teresa Hamilton, held lectures on first aid and nursing. Beatrice Butler was one Hobart woman who attended at least the first lecture in a series of eight on first aid. Lady Hamilton had three doctors to give the talks, she wrote in her diary.[35] The unmarried women in the audience were to sit an examination at the end of the course, but married women did not have to do so, as they were supposed not to have so much free time. Seventy women attended, of "all classes", and Lady Hamilton gave an introductory speech, "rather an ordeal I should think", telling the audience that they were "not to make a joke of it" and they must attend two-thirds of the lectures or they would not be allowed to attend the next course, which was on nursing. The eight lectures cost three shillings.[36] Again, what eventuated is not clear.

In 1891, on the same pattern, Teresa Hamilton organised a series of lectures on First Aid, given by Dr Giblin. The idea was highly praised, as the information would teach women how to nurse their families and, possibly, help to earn a livelihood. The maximum number in the audience was 30, which was soon filled, and at the end of the course an examination was given, which all candidates passed. The lectures began in June and were so popular that two classes were held. In August, a second course of lectures was given on Nursing; there were five lectures and 24 in the audience. Nineteen sat for the examination, which was part oral and part written, and again all passed. There was also a course of lectures on surgical and typhoid nursing to those who had passed the first course. Similar lectures were given in Launceston and Campbell Town.[37]

On other occasions, Teresa Hamilton lectured herself, to various audiences but usually on topics concerning health and diet. In 1891, she gave a series to the Young Women's Christian Association on Health, Hygiene, Food and Clothing. She explained to her audiences the difference between nitrogenous and carbonaceous food, and urged a balanced diet of fruit and vegetables, meat, grains, cheese and milk puddings and the avoidance of unwholesome food. She condemned alcohol, and spoke about digestion and "banting" (slimming).[38] She also spoke to poor women in Wapping, using simple language to explain about treating wounds and illnesses, and bandaging. She gave at least three lectures to the women of St David's parish and, in 1892, to the women of Glenorchy on ambulance work.[39] She moved to a different topic when she spoke to the pupils of the Ladies' College for an hour on the Education of Girls.[40]

In 1892, Teresa Hamilton moved beyond mere lecturing and formed the Nursing Band, whose members visited the poor and attended to illness. They had to have a St John's Ambulance certificate or similar qualification. Teresa Hamilton gave a series of lectures for the Band and for anyone else interested, talking about ambulance and nursing work generally. The Band had eight or nine members and, by December 1893, they had attended 80 cases and paid over 700 visits. In the later 1890s, the Band became the District Nursing Association.[41] In the same year as she formed the Nursing Band, Teresa Hamilton was connected with the establishment of a convalescent home for "all overworked women needing a rest". Fees were low, and a committee raised funds to maintain the home.[42]

Teresa Hamilton's interests extended beyond nursing. She would not have been a charitable governor's wife if she had not tried to rescue prostitutes and, in 1889, she founded the undenominational Anchorage Refuge Home. It was run by a volunteer committee and a paid matron, and aimed to "help the poor fallen ones lead a good and useful life",[43] by caring for pregnant women and their subsequent babies for a year. The aim was to instil mother-love into the women, as the great incentive to acquire and retain their social position. The women were then found situations as domestic servants, preferably where they could keep their children with them. The committee tried to impress the fathers with their responsibility and assisted each fallen woman once only. Teresa Hamilton not only founded the home but was much concerned with its management, and once, when the secretary was absent for two months, undertook these duties herself.[44] This was another institution which lasted after Teresa Hamilton's departure, as it ran successfully until 1911.

Teresa Hamilton continued a traditional activity by becoming patroness of the Dorcas Society, but she did not appear excited by this work. She attended only one committee meeting, and paid one further visit in 1892.[45] The Society ran successfully without her help and, clearly, she liked running activities rather than being one of a committee of an organisation which already had leaders.

She did, however, assist with one established venture, the Hobart Ladies' College, which her daughter Mary attended.[46] The Walker family had a great deal to do with this establishment, for Sarah taught there and James was the secretary of the governing Board. In 1889, he described how competently Teresa Hamilton distributed the prizes at the end of the year.[47]

> "She did the business very well, & made a very neat speech afterwards. Sensible, well expressed, & without any hesitation, & she knew — what so many men don't — when to leave off. It compared very well with Sir Lambert's [Chief Justice, member of College council]. He was very funny. He spoke of the misfortunes of the College & the changes we had had of one Principal after another. 'In fact', he said, 'the great drawback to the College in the past, has been the instability of its Principals'. He did not think that it sounded like 'Principles'! I heard a little laughing, &

told him afterwards that it was too bad to give us away in that fashion. He also praised Col. Cruikshank as an examiner & said his great merit was that 'he would condemn the right as well as correct the wrong'. He then corrected himself and said, 'At least, praise the wrong, & correct —' and he had to try again before he got it straight."

The next year, Teresa Hamilton was made a member of the Council, after asking Walker three times for the position.[48] The College also gained a new principal, Miss Piper and, after meeting her, James Walker commented, "I hope she will have decision enough to manage the Council, especially since Lady Hamilton is on it".[49] In 1890, the College held a Musical Evening, and, wrote Sarah Walker, "of course Her Excellency was there. After Lady H. had come Miss P. came to the back with the girls and wanted to stay there but I told her she must go & sit with her so at last very reluctantly she went".[50]

Every so often, James Walker recorded an action of Teresa Hamilton's on the committee. At her first meeting she was "very placable", but this did not last.[51] At her suggestion a sub-committee, including herself, was formed to discuss with the principal improving the methods of teaching. This seems a sensible suggestion, given that College numbers were declining, but Walker seemed to scorn it.[52] At the end of the year, Teresa Hamilton again chaired the College prizegiving. According to Walker, she "bossed the whole show, gave away the prizes, and made a speech. She is very great on education, the teaching of languages and art etc etc."[53] Several other Council members remarked to him that Teresa Hamilton "criticised from a professional point of view",[54] with which they were not happy. Again, criticising from a professional point of view seems well suited to the governing body of a school, and it is not clear why Teresa Hamilton's activities were not approved by the other, male, Council members, unless it was because a woman was speaking out.

There is little more information from the Walkers about Teresa Hamilton and the College, for James ceased to be secretary and, in 1892, Sarah began her own girls' school. She began with a housewarming but did not ask Teresa Hamilton, because Mrs Montgomery, the Bishop's wife, was bound to be there, and the two women did not agree.[55]

A different activity for Teresa Hamilton was that she was said to be interested in encouraging women's sport. There is not a great deal of evidence for this, but she and the Governor and "nearly all the fashionable world" attended a Ladies' Cricket Match in 1890, and the next year she twice invited the pupils of two girls' schools to Government House to watch a cricket match between teams from the schools, then to partake of afternoon tea.[56]

There is more evidence for Teresa Hamilton's interest in cultural activities. She was reported to have encouraged the Gaiety Players, an amateur group from the upper classes, and certainly attended their performances.[57] She was interested in art and, in 1891, formed the Hobart Sketching Club, whose members, at one stage, went to New Norfolk to sketch.[58] Teresa Hamilton was the first president of the Launceston Art Society and was actively interested in the establishment of Art Galleries in Hobart and Launceston. In 1891, she asked James Backhouse Walker to draw up fresh rules for the Art Association. "Her Ex. is too exacting to make working with her pleasant," wrote Walker. "The only thing is that she doesn't spare trouble herself — in fact it is she who keeps the thing going."[59] She also encouraged at least one individual artist. At one stage, William Piguenit, just returned from a trip inland, gave a talk about the beauties of the highland scenery. Teresa Hamilton was in the audience, and it was at her suggestion that the monochrome paintings illustrating the lecture were purchased by the Government, by a special vote of £100.[60]

The association for which Teresa Hamilton is best known, probably because it bears her name, is the still-existing Hamilton Literary Society. In July 1889, she invited a number of ladies to Government House to form a literary group, which she named, rather condescendingly, the Nil Desperandum Society. She later commented that it was formed for "mutual pleasure and intellectual profit".[61] Learning to think and judge is a form of education we all need, she wrote, and to get out of our grooves is profitable.[62] She chose the subjects and the speakers, and each member was given a topic, on which she presented a paper at one of the fortnightly meetings at Government House. Other members then discussed the paper. There was a great variety of topics, from "Manners Maketh Man" to Trade Unions, and Sarah Walker commented that friends of hers thought the society "will be very good", though the members were a "funny mixture". She was asked to join and wrote unenthusiastically, "I suppose I had better".[63] Later she made several caustic comments about the Literary Society. She noted that one woman gave a paper on Browning, "(!!!). A little subject just to fill up I suppose".[64] When she herself attended, however, she became keenly interested in writing her paper on Trade Unions, and told her sister that she had begun to enjoy the Society.[65]

In August 1890, Teresa Hamilton entertained about a hundred women at Government House to celebrate the Society's first anniversary, but trouble soon arose. In the following summer, Hobart was packed with visitors, including six naval ships, and Teresa Hamilton gave the most glamorous ball the city had ever seen. Not surprisingly, the January meeting of the Nil Desperandum Society was sparsely attended, and in the next month a full-scale argument erupted.

"There is a grand quarrel between Lady H. and the Dobsons," wrote Sarah Walker.[66] Ethel Dobson, daughter of Sir Lambert Dobson, wrote the society's secretary a note, which Teresa Hamilton considered insulting, though the secretary, Miss Patty Mault, thought it was an ordinary note of apology. (Patty came from the family who "worshipped the aristocracy".) Teresa Hamilton demanded Ethel's resignation, Ethel said she did not think she had done anything wrong, and though Patty Mault begged her not to continue the quarrel, "Her Excellency was obstinate". Sarah Walker thought her "very foolish and undignified", and put the quarrel down to the "never friendly feeling" between the Hamiltons and the Dobsons, and the low attendance in January, which had annoyed Teresa Hamilton, who thought it was due to a rush after officers. Maud Montgomery tried to make peace, but "Lady H. does not love Mrs M. — she is too independent", so her attempts did no good. Meanwhile Ethel Dobson made matters worse with a second letter, written with help from her father. It was held to be in bad taste, "very Dobsony", but Sarah Walker thought that Teresa Hamilton's course was "altogether out of proportion to the offence".[67]

At the next, very tense, meeting the matter was discussed. Only two of the 17 members were on Teresa Hamilton's side, but she told the meeting that all who thought Ethel Dobson had been hardly treated should resign. Ten did so,

the younger ones going up "white & trembling like martyrs to the stake. You know they stand in great awe of Lady H. and she has been very kind to some of them". Patty Mault asked Teresa Hamilton whether her own daughter would not have asked her father's help in such a situation, and she replied, "Big as she is I would have her whipped", and looked furious enough to have struck Miss Patty in the face, Maud Montgomery told Sarah. "It was rather dreadful was it not?" Sarah commented.[68] She added, "Her Excellency told them what they owed to her & the courtesy due to her from her position & Miss Patty said Lady Hamilton is it not from you we look for it before all others... Of course Lady H. will never forgive any of them".[69]

Later, Sarah had a chance of finding out the inside story. She and her friend Poppy Clarke walked to Government House to say how do you do to Lady Hamilton, who insisted on them having coffee. She "dismissed the servants & drew up our chairs & was settling down to a long narrative when to our extreme annoyance in walked Mr & Mrs James", who stayed until it was time to go home, so Sarah never did hear Teresa Hamilton's explanation. "Both [Poppy] and I had been wanting to hear what she had to say."[70]

There was a reconciliation, then another "bust up", and Teresa Hamilton returned the subscriptions of those who had resigned, to their fury. A dance at Government House in April was poorly attended, and finally in May the hatchet was buried.[71] The Literary Society continued, and in 1892 was still meeting fortnightly at Government House and discussing such topics as the works of Rudyard Kipling (with animated debate for and against), and "There's Nothing like Leather".[72]

When Teresa Hamilton departed from Tasmania, she chose a committee to run the society, which, the next year, was renamed the Hamilton Literary Society in her honour. By the time of her death in 1932, it was a venerable body, the oldest existing such society in Australia. As well as the Society itself, Teresa Hamilton was reported as founding a reading society for the younger set, and a "Search Club" for women who spent most of their time in their homes and needed guidance as to how to spend their leisure, but these must have been small bodies as they were not mentioned at the time.[73]

Teresa Hamilton gave her support to other literary institutions. In 1892, the Australasian Association for the Advancement of Science held a congress in Hobart. Many papers were given, and women flocked to hear them.[74] At one stage Sarah Walker arrived just as Teresa Hamilton was reading a paper by another author on decorative art in Australia. She read it very well, considered Sarah. An outcome of the conference was the idea of reading circles, under the auspices of the Australian Home Reading Union. A committee was appointed to run it: "Lady H. was put on it & by her influence Miss Chapman & we were all in terror lest either should be made officers in any way", but in the end Sydney was made the headquarters with the New South Wales governor's wife the president.[75]

Despite the Literary Society quarrel, these actions of Teresa Hamilton, though new to Tasmania, were generally acceptable. They encouraged women to move outside the old domestic role, meet in groups and act, but in areas always acceptable as part of women's role: literature and art, nursing, caring for the poor and unfortunate, and teaching girls. But Teresa Hamilton went further than this. In two areas, she encouraged women not only to act but to influence public opinion and try to change the laws. Women did this in Tasmania on only three occasions before 1914, and Teresa Hamilton was involved in two of them.

The first was temperance. Temperance societies had existed on and off in Tasmania since the 1830s, with women playing a very minor role. In 1873, the Women's Christian Temperance Union was formed in the United States, and women's temperance activity began in Tasmania in 1885, when an English advocate visited and began a Hobart branch. This faded, but was revived in 1886 by a further visitor. She formed a branch of the American WCTU, under which members signed the pledge and aimed to spread Gospel Temperance and Purity, to advocate equality of men and women, and to Do Everything, that is, further any cause which was seen as contributing to a purer society.

Interest waned; in 1899, a third visitor, Jessie Ackermann, revived it, but once again activity faded. Ackermann returned in 1892 and resuscitated or re-formed over 20 branches in Tasmania. In Hobart, she visited hotels to speak and pray, gave stirring addresses, and spoke at a torchlight procession and at drawing-room meetings, in an attempt to reach all classes of society.

In March 1892, the Union's committee sent a deputation to ask Lady Hamilton to invite Miss Ackermann to speak at a drawing-room meeting at Government House.[76] As seen above, Teresa Hamilton had negative feelings about alcohol and was interested in many areas espoused by the Union, and she duly held a meeting, which was described as a success, despite bad weather.

This was a brave move for the governor's wife; the Union consisted mainly of lower-middle-class women, far removed from her usual circle, and was promoting causes which were not generally held in high regard by elite circles: temperance, purity and women's rights. The Walkers do not mention such activity in their letters, and Alix gave them little sympathy in her weekly column. Nevertheless, Teresa Hamilton sent the Union committee a message, saying she was sympathetic to their work and would help in any way possible.[77] She chose the area of their work with which she had shown most interest in the past and, in June 1892, gave a lecture on Hygiene to 70 women. She also spoke at a cottage meeting, giving a "very instructive address" to about 16 Mt Stuart "settlers' wives" who came through muddy roads to hear her speak and were reported to be very pleased with the meeting.[78] In May, she held an afternoon tea at Government House to help spread the Union's message, and many ladies attended. Though Alix described cricket matches, a dance and a literary society meeting at Government House in this period, she did not mention the Union meeting.[79]

After this, Teresa Hamilton's contribution to the Union appears to have waned and, in any case, she left Tasmania within six months. Perhaps the increasingly radical activities of the "Women's Righters" of the Union, or Sir Robert, advised prudence in becoming involved in this work. She was, however, one of the few upper-class women to have shown any interest in or support for the Union.

Teresa Hamilton's second radical project was the Women's Sanitary Association. In the second half of the 19th century civic reform, particularly the need for better sanitation systems, became a popular cause in towns all over the western world. Hobart was no exception, and several typhoid epidemics in the 1880s brought demands

for a better sanitary system. Unlike the Launceston City Council, the Hobart body was backward in its approach to city government. Rapid population growth from 1881 to 1891 highlighted defects in civic management, and the need for municipal reform was obvious to forward-thinking people — as noted earlier, the bad smell in Hobart streets was a problem when the Hamiltons were welcomed in 1887. Anxiety over Council inertia prompted the formation, in August 1891, of the all-male Sanitary and General Improvement Association of Hobart, which worked for underground drainage.

Women's involvement in the issue was prompted by a lack of achievement by this group. According to Mrs Hannaford, a later member, the prevalence of typhoid in 1889 and 1890 caused many to consider what could be done.[80] Emily Dobson, a woman of a similar stamp to Teresa Hamilton, conferred with the Ladies' Christian Association and afterwards Teresa Hamilton, who had shown herself interested in this area from 1887. The *Tasmanian Mail* said that the lack of permanent response to Teresa Hamilton's message was due to "the dreadful apathy of which as a community we are the victims to such a deplorable degree".[81]

In September 1891, it appeared that a Deep Drainage Bill, which the male association had been advocating, would not be passed by Parliament, and Teresa Hamilton convened a women's meeting. She was supported by eight of Hobart's leading women, including Emily Dobson and Maud Montgomery, and the audience filled the Town Hall to overflowing. Teresa Hamilton told them that it was their duty and privilege to act in this question of life and death, that women with any notion of responsibility must feel that it was as health conservers that their highest duty lay. Man's life and income depend on his health, his and those of "all those gentle clinging souls who depend on him and call him father, brother, supporter, friend".[82] Typhoid, she said, came from insufficient sanitary arrangements, and nothing was being done. "You, a band of warm-hearted, earnest women", she told her audience, had asked her, as "a wife and a mother in this city", to assist in petitioning Council and Parliament to act. Such an appeal, including flattery, emotion, notions of ideals, duty and a possible threat to income, was clearly the method Teresa Hamilton thought best suited to moving Tasmanian women.

Emily Dobson then spoke, more critically of men, and the meeting agreed to organise two petitions, to Parliament and the City Council, to pass the Deep Drainage Bill. As it was Thursday and the petitions had to be ready by the following Tuesday, immediate action was necessary. Hobart was divided into districts, and all volunteers were given an area to canvass for signatures. Great enthusiasm was shown, and Alix thought success likely in an endeavour led by "two such earnest, hardworking, good and clever women as the wives of our Governor and Bishop".[83] At the close of the meeting a vote of thanks was passed to Teresa Hamilton, whose interest in the advancement and prosperity of the city had always been manifest.[84]

A large number of women collected 5740 signatures for one petition and 5413 for the second. Such unprecedented action by women attracted a good deal of attention throughout Tasmania. On the Monday, a second meeting received the signatures, and Teresa Hamilton told the audience that, although there had been a great deal of excitement over the first meeting, the work must be continued. Three resolutions were to be put to them. The first was introduced by Maud Montgomery, who told the women their duties as Christians regarding sanitation: they should keep their homes and streets in such a condition that they would not be ashamed if God himself walked through Hobart. She also urged women to report neglect of duty by nightmen, and to give their children a knowledge of sanitary science. The resolution was that, by voting themselves as ratepayers or by influencing their husbands, women would try to elect councillors who would act in the matter. The second resolution asked women to receive sanitary instruction and report unsatisfactory sanitary matters; the third that a Health Officer and Inspector of Nuisances be appointed. All resolutions were carried.[85] The petitions were duly presented, and Parliament passed the Deep Drainage Bill.[86]

A third women's meeting was less well attended, though all the active women were present. It decided to form a Women's Sanitary Association, with Teresa Hamilton as president and Emily Dobson as secretary.[87] Women who had taken part in the canvass reported astonishment at the intense eagerness by many poor women for improvement, and noted how clean most "little backyards"[88] were, so Teresa Hamilton organised cards to be printed, containing rules for household cleanliness and nursing, and members aimed to visit every house in Hobart, distributing cards and inquiring into sanitary conditions. Members were also told to read Ibsen's *Enemy of the People*.[89] This radical play, written in 1882, dealt with a society's attitude towards a clean water supply, so such advice was remarkably progressive.

By December 1891, the 80-member Association felt that much had been achieved. It looked as if the Council would implement reforms, and the visits by members had brought to light many nuisances and evils. "Women have done good work in stirring up public opinion",[90] and would not rest until all these nuisances were swept away, and the same attention paid to the state of the dwellings of the poor as those of the rich. Women had no power to carry out reforms, considered a member; they could only urge the need for it on the authorities by pointing out evils and "giving the authorities no peace till those complaints are addressed".[91] Issues brought up included butchers' care of meat and fishermen's of fish, and rubbish collections. At one meeting, Teresa Hamilton warned members to avoid a spirit of antagonism and concentrate on education about sanitation.[92] She assisted in this by providing a series of articles for the *Mail*, on "Sanitation and Public Health", Ventilation, Nursing, the importance of Health, and so on.[93]

In 1892, the enthusiasm of the Association seemed to wane somewhat, though work continued and, in July, the Association met the local Board of Health, whose members assured the ladies that they were doing all that they could.[94] There was criticism of the Association: a correspondent wrote in the *Mercury* that he or she was glad to see aldermen objecting to its "foolish statements and reports", and advised aldermen to take no notice of these. The Association was doing much damage by letting it go forth to the world that Tasmania was dirty.[95] The Editor commented that the Association had caused the authorities to move, "and that is a notable achievement".[96] Another correspondent was much amused at the indignation of aldermen who "think their dignity is imperilled by women suggesting reforms".[97] Teresa Hamilton had another series of articles printed in 1892; subjects included "The Want of Sanitation in the

Times of our Forefathers"; "The Ground beneath our Houses"; "The Personal health of Members of our Households"; "Sanitary Arrangements of Our Houses", and "Health and its relation to Temperance".[98]

The Association continued its work in the 1890s, but itself acknowledged that it achieved little, giving as reasons a lack of sympathy and co-operation among people generally, and women's fear of identifying themselves with a movement called "unfeminine", though it was not at all, as it was women's duty to help humanity. Members had been called ugly names and told they were trying to do men's work, but when men did nothing, women felt they had to act.[99]

What the Association had achieved was that women had been seen acting in public, competently running meetings, and trying to change public opinion and to influence Parliament and the City Council. Women criticised men's handling of sanitation, debated issues with men and stood up to them firmly, showing themselves independent of masculine guidance and authority. Such activity was a considerable achievement for Tasmanian women of the 1890s, and it was accepted at the time that this "noble stand" was led by Teresa Hamilton.[100] As Alix wrote:[101]

> "The part that Lady Hamilton has taken is one that reflects honour, not only upon herself, but also upon His Excellency the Governor, whose term of office she is working to make so marked in its usefulness. That such an influence for the good of the people should proceed from Government House itself is so fitting and appropriate that people in general are apt to overlook it for that very reason. It can never be forgotten, however (and the truth will be more generally acknowledged in all probability when this kindly lady has left our shores) what time and pains Lady Hamilton has expended in her endeavours to make the women of Tasmania interested in matters relating to the health and comfort of themselves, their families, their dependents and their houses, as well as the research she has initiated into standard works on hygiene, so as to enable her to furnish her readers and listeners with the best information procurable on every branch of the subject she takes such an interest in."

In November 1892, it was announced that the Hamiltons were returning to England. Alix reported[102] that regret was "very sincere and general"; the Governor would be missed for his courtesy, considerateness and kindness, but his loss would be felt less than that of Lady Hamilton, "who had done so much for the good of Tasmania". Not only had her private acts of kindness been numerous, but:

> "If a masterly inactivity in political matters is desirable in a Governor, a masterly activity in social affairs is equally desirable in a Governor's wife, and this Lady Hamilton has always displayed in her efforts for the intellectual, artistic and hygienic improvement of the people. Innumerable are the meetings of all kinds she had presided over, the concerts and other entertainments she has patronised, the speeches she has made, and the journeys she has undertaken for the forwarding of altruistic schemes."

The next week Alix returned to this topic.[103]

> "Lady Hamilton has taken so active a part in all useful works that it is hard to realise what Tasmania will do without her. We want more women who will strive to do what is right, happen what may, and who will go on towards a purposeful goal without being drawn to the right hand or to the left by useless regard for the many different opinions of a more or less variable society. There are many who have misjudged her at times, but who, appreciating her singleness of purpose and strength of character, have been glad to acknowledge to her that they were wrong, and to join with others in expressing the high respect, regard, and admiration they must always feel for her, both as a Governor's wife and as a woman."

Alix thought that Teresa Hamilton's activities had had an important effect on Tasmanian society. The tone seemed higher and more earnest, there was more interest taken in work for the good of the community, and more pains by the young in self improvement. Teresa Hamilton had encouraged women and girls to take more interest in those around them, and in art and literature. There was less provincialism and "cliquism", and Hobart compared well with larger cities in respect of culture and refinement.[104]

In the week before she left, Teresa Hamilton certainly undertook a variety of activities, as well as supervising the packing of a large household after a residence of six years. She attended a children's concert, held the third in a series of large dinner parties at Government House, watched a polo game, presented the prizes to the pupils of Miss Mackenzie's gymnasium and the pupils of the Ladies' College (where she hoped that another woman would be appointed to the governing Council in her place — but alas, after Teresa Hamilton's departure the College closed), attended a "very clever" lecture by Madame Henry, sent "a kindly letter of congratulations and a lovely bunch of carnations from Government House" to a bride, and took part in several farewell activities — nothing very novel, perhaps, but a considerable effort at such a busy time. She also personally supervised the decoration of the Government House reception rooms with maidenhair fern and scarlet cacti.[105]

This was done in preparation for a large reception at Government House, to which a thousand people came (including Lady Dobson, Miss E. Dobson, the Misses Walker, J.B. Walker, but not the Maults). Five hundred and fifty shook hands with the Hamiltons, "all anxious to say farewell to the most generally popular Governor and Governor's wife we have had for many years".[106] The vice-regal couple was presented with an address from the City Council, in which Lady Hamilton's "unostentatious charity, benevolence, and bright example" were praised, and later she was presented with addresses from the women of southern, then northern, Tasmania.

The southern women, organised by a committee which was headed by Lady Dobson and Mrs Montgomery, collected money to present Teresa Hamilton with a diamond ring, but she intimated that she could not accept so handsome a present. So she received a gold bangle, and the rest of the money went to the Benevolent Society. The presentation and the committee's words of gratitude for her "work amongst us" so affected Teresa Hamilton that she found some difficulty in replying; then she thanked the ladies, and said that her activities were done from a sense of duty first and pleasure afterwards, and that she had made so many friends that she would always look back on her Tasmanian years with delight.[107] This was only a year after the Literary Club quarrel, but either everyone was conscious of saying the right thing, or they had indeed come to admire Teresa Hamilton's qualities.

Just before she left, Teresa Hamilton was presented with five addresses in the Town Hall, from the Anchorage committee, the Women's Sanitary Association, the Convalescent Home, the Young Women's Christian Association, and one large one, illuminated with paintings of Tasmanian flowers and berries and bound in black morocco, from the women of southern Tasmania, with 1600 signatures. Teresa Hamilton said in reply that she had received much praise, but the work had mainly been done "by the women of the place". Her last function in Hobart was to attend a meeting of the Home Reading Union in the Royal Society room of the museum. Here she was given a standing ovation.[108]

How can Teresa Hamilton's contribution to Tasmania be summed up? Clearly she was a forceful woman, and this trait was encouraged by the authority which came with her position as Governor's wife, and perhaps from a feeling common to migrants from Britain, that they are bringing their superior knowledge to improve the colonials. She also felt that she was doing her duty, and this can encourage people to put forward their own point of view at the expense of others'. Her overbearing streak could get out of hand, as in the Literary Society quarrel. The Walkers' letters, however, show that for them at least this was but one fault among a number of positive aspects, and if Alix's column was true and not merely sycophantic, many others felt the same way.

Teresa Hamilton did a great deal to bring new ideas of women's role to Tasmania, but there were many aspects of first-wave feminism with which she had no obvious sympathy. She displayed no interest in women's suffrage, which was not an issue in Tasmania in her period, or in improving conditions for working women, or opening professions to women — though as her daughter later became a doctor, still unusual for women at this time, she was presumably sympathetic to this.[109] She showed no inclination to change the basic structure of society, and said nothing to challenge the traditional view that women's aim in life should be marriage, and the intelligent care of husband and children. Certainly her address to the first meeting of the Women's Sanitary Association, where she told women that it was as health conservers that their highest duty lay, and they and their children were "gentle clinging souls", does not show much militant feminism.

What Teresa Hamilton was interested in was promoting what she felt were suitable interests for women: their intellectual activity and education, and the welfare of their families. If this meant being active in public, so be it. Women were to be encouraged into joining societies to promote both culture for themselves, and acting to promote the good of society generally, as in sanitation and temperance. Teresa Hamilton was not afraid, as Alix wrote, "to do what is right",[110] neither was she afraid of criticism, and she would challenge anyone, men included, to gain her aims and improve society. Before Teresa Hamilton's arrival in Tasmania, women's public activity had been virtually nil, with hardly any women's societies. By the time of her departure, women had held public meetings, debated issues with men, tried to change public opinion, gone into the streets to canvass for signatures for petitions, challenged the City Council and Parliament, and, in short, had made their voices heard without masculine guidance. And the leading lady in the colony not only led this activity but had told women that it was their duty. As well, there were numerous women's societies, which were quite accepted. At first, women's reaction to Teresa Hamilton was lukewarm but, as they became used to her, they were more receptive. She certainly awakened women's interests in the possibilities open to them.

Another facet of Teresa Hamilton's activities was that she tried to reach all classes, at a time when many governors' wives concerned themselves solely with the upper class. Teresa Hamilton presumably invited only these ladies to her entertainments (though there was that "funny mixture" at the Literary Society), but she included all women in her addresses, and was not afraid to consort with the lower-middle-class Women's Christian Temperance Union.

It is instructive to compare Teresa Hamilton with her predecessor Jane Franklin: both forceful women, both keen to improve society for society's good and both convinced that they knew how to do it. Teresa Hamilton, however, did not receive the criticism that Jane Franklin did, probably because she maintained always that she was only doing her duty as a woman, in woman's proper sphere of action. And she did not venture into that absolutely masculine realm, government.

Nevertheless, she did challenge men and encouraged other women to do so. There was little criticism of this, probably because, in the respectable 1890s (as opposed to the 1840s), few people in Tasmania dared to criticise, at least openly, the actions of the Governor's wife. Perhaps it is telling that in the address presented to the Hamiltons on their departure by the, all-male, Hobart City Council, Teresa Hamilton was praised for acceptable feminine actions only; her unostentatious charity, benevolence and bright example, from which one might have thought her merely another quiet, good governor's wife. It was the women who thanked Teresa Hamilton for her "work".

So Teresa Hamilton left Tasmania with its structure much as it had been in 1887, but with women shown how to play a much more active role within that structure. She is the foremost illustration of the fact that first-wave feminism was introduced to Tasmanian women from outside, by those whose husbands held leading positions, such as Teresa Hamilton herself, Maud Montgomery and a later bishop's wife, Josephine Mercer; or by visitors who came to promote a particular cause, such as Jessie Ackermann and temperance. The only really active Tasmanian-born woman was Emily Dobson. She had been a usual wife and mother until 1891, when she suddenly became active, as seen in the Women's Sanitary Association. In the following years she founded a number of societies and was the leading light of such feminism as existed. It was very much on the pattern started by Teresa Hamilton and could very well have been inspired by her.

The rest of Teresa Hamilton's story is soon told. She returned to England to sadness: first her mother died, then Sir Robert in 1895, and in 1908 her daughter Mary, who was only in her twenties. Fortunately her son survived and lived near her. Teresa Hamilton continued to write articles and read papers, including one on Tasmania, and kept in touch with her friends there. In the early 1930s, she was hostess, by proxy, at reunions of the Hamilton Literary Society, her sketching club and her ambulance class, sending a cheque to cover expenses. She died in Bath at the age of eighty. Her obituary in the *Sydney Morning Herald* praised her as a patron of the arts and described her promotion of literature and art,[111] as did her one line in her husband's entry in the *Australian Dictionary of Biography*. Teresa Hamilton deserved more than this.

## REFERENCE MATERIAL

The following abbreviations are used for sources repeatedly cited in the text.

Publications

| | |
|---|---|
| *ADB* | *Australian Dictionary of Biography* |
| *CN* | *Church News* |
| *Cyc. Tasm.* | *Cyclopedia of Tasmania* |
| *Merc.* | *Mercury* [Hobart] |
| *SMH* | *Sydney Morning Herald* |
| *TM* | *Tasmanian Mail* |
| *WA* | *Walch's Almanac* |

Correspondents

| | |
|---|---|
| IW | Isa Walker |
| JBW | James Backhouse Walker |
| MW | Mary Walker |
| SW | Sarah Walker |

Archival Material

| | |
|---|---|
| AOT | Archives Office of Tasmania |
| B | University of Tasmania Archives — B |
| CSD | Colonial Secretary's Department [Archives Office of Tasmania] |
| RS | University of Tasmania Archives — Royal Society |
| UTA | University of Tasmania Archives |
| W | University of Tasmania Archives — W |
| WCTU | Women's Christian Temperance Union minutes |

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## NOTES

1. *ADB 4:* 331-332.
2. Alexander: chs 1-7.
3. Alexander: ch. 8.
4. Alexander: ch. 9.
5. Alexander: ch. 11, quotation p. 142; RS 1/1(34).
6. RS 1/1(34).
7. *Cyc. Tasm. 1:* 220; *WA* 1863: 122; 1865:122; CSD 4/37/455; Serle: 203.
8. Quoted in Ellis: 202; Serle: 204-205.
9. *WA* 1882: 191; *Cyc. Tasm. 1:* 220.
10. *ADB 6:* 203.
11. *SMH* 13/08/1932; Morris: 17; *Merc.* 12/03/1887; Burke: 783.
12. Weigall.
13. Weigall: 5, 27; Morris: 51; Burke: 783.
14. *ADB 4:* 331-332; *Merc.* 12/03/1887; Morris: 15.
15. Weigall: 95.
16. *SMH* 13/08/1932.
17. Weigall: 86, 95.
18. M. Blackwood, South Hobart, pers. comm.
19. Morris: 51.
20. JBW/MW 21/06/1891, W9/L2/6.
21. Quoted in Morris: 17, 78.
22. JBW/MW 16/02/1890, W9/L2/5.
23. *Merc.* 12/03/1887.
24. Ibid.
25. *TM* 12/11/1892.
26. C. Alexander: 148, 149. W9/L2/6, 18/10/1891, Lady Hamilton gives an "evening" when the Australian Squadron is in port; a ball at Government House, JBW/MW 12/03/1890, W9/L2/5. See also *TM* 2/04/1892.
27. SW/MW 21/10/1890, W9/L4.
28. *TM* 7/05/1892.
29. *TM* 7/05, 2,9,28/04/1892; Weigall: 93.
30. *Cyc. Tasm. 1:* 27.
31. Robson, vol. 2: 126-127.
32. Morris: 17, 74.
33. *TM* 26/09/1891 report of 1887 address.
34. *TM* 23/05/1891.
35. Diary of Beatrice Butler 18/06/1889, B9/6 2(2).
36. Ibid.
37. *TM* 23,30/05, 20,27/06, 29/08, 12/09, 10,31/10, 7/11, 28/12/1891; 18/06/1892; 10/06/1893.
38. *TM* 14,21/11/1891.
39. *TM* 11/06, 22/08, 17/10/1891; 4/06, 15/10, 5/11/1892.
40. *TM* 16/08/1891.
41. *TM* 18/06, 24/09/1892; 30/12/1893; 1/07/1897; 16/09/1899.
42. *TM* 10/10/1891; 5/03, 17/09, 29/10/1892.
43. *Merc.* 16/09/1891.
44. *TM* 23/09/1899; *Merc.* 16/09/1891.
45. Minutes of Dorcas Society, March 1887, November 1892, UTA.
46. *TM* 26/11/1892.
47. JBW/MW 22/12/1889, W9/L2/A.
48. SW/MW 22/01/1890, W9/L.
49. JBW/MW 21/01/1890, W9/L2/5.
50. SW/MW 22/06/1890.
51. JBW/MW 27/01/1891, W9/L2/5.
52. JBW/MW 12/07/1890.
53. JBW/MW 21/12/1890, W9/L2/5.
54. Ibid.
55. SW/MW 27/03/1892, W9/L4/6.
56. JBW/MW 18/03/1890, W9/L2/5; *TM* 21,28/05/1892.
57. Bolger: 184; *TM* 7/05/1892.
58. *TM* 25/04/1891; 1/09/1894; 29/05/1897.
59. JBW/MW 15/11/1891, W9/L2/6; Morris: 15.
60. *SMH* 13/08/1932.
61. *TM* 1/09/1894.
62. *TM* 1/09/1894; 21/04/1900; 14/09/1908.
63. SW/MW 23/04/1890, W9/L4; see also IW/MW 27/09/1889, W9/11/6.
64. SW/MW undated 1890, W9/L4/4(9).
65. SW/MW 8/02/1891, W9/L4/4.
66. Ibid.
67. C. Alexander: 148; SW/MW 8/02/1891, W9/L4/4(21).
68. SW/MW 21/02/1891.
69. SW/MW undated [March 1891], W9/L4/4.
70. SW/MW 2/05/1891, W9/L4/5(9).
71. JBW/MW 22/02, 1,8,15/03, 5/04,10/05/1891, W9/L2/6.
72. *TM* 21/05, 23/04/1892.
73. *SMH* 13/08/1932; Morris: 18-19.

74. JBW/MW undated 1890, W9/L2/5.
75. SW/MW 12/01/1892, W9/L4/6. The local Hobart secretary was Caroline Morton.
76. WCTU 31/03/1892.
77. WCTU 28/04/1892.
78. WCTU 30/06/1892.
79. *People's Friend* May 1892; *TM* 2,9,16,23/04, 7,21,28/05/1892.
80. *TM* 22/09/1900.
81. *TM* 19/09/1891.
82. *Merc.* 10/09/1891.
83. *TM* 12/09/1891.
84. *TM* 12/09/1891; *Merc.* 10/09/1891.
85. *TM* 19/09/1891; *Merc.* 16/09/1891.
86. *CN* December 1891: 563.
87. *WA* 1892: 290.
88. *TM* 3/10/1891.
89. *TM* 3,31/10/1891.
90. *CN* December 1891: 563.
91. Ibid.
92. *Merc.* 21/11/1891.
93. *TM* 19,26/09/1891.
94. *Merc.* 13/07/1892; *TM* 18/06, 3/09/1892.
95. *Merc.* 18/09/1892.
96. Ibid.
97. *Merc.* 20/09/1892.
98. *TM* 13/08/71892.
99. *TM* 22/09/1900.
100. *TM* 19/09/1891.
101. Ibid.
102. *TM* 12/11/1892.
103. *TM* 19/11/1892.
104. *TM* 19,26/11/1892.
105. *TM* 26/11, 3/12/1892.
106. *TM* 26/11/1892.
107. Ibid.
108. *TM* 3/12/1892.
109. *SMH* 13/08/1932.
110. *TM* 19/11/1892.
111. *SMH* 13/08/1932; Morris: 79; *TM* 3,31/08/1895; 28/11/1896; 21/07/1900; 4/05/1901; 10/01/1903; 12/09, 24/10/1908.

# FEATURES OF JURASSIC DOLERITE INTRUSIONS AT CAPE SURVILLE, LYNWOOD, SINGLE HILL AND MOUNT NELSON, TASMANIA

by David Leaman

(with one table, four text-figures and one plate)

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The intrusive features associated with the Jurassic dolerites of Tasmania are generally well displayed, but rarely is more than one feature visible at any one site. The great range of characters can, however, be reviewed and inspected by visiting only four sites. Each site provides information which can constrain any hypotheses for mechanisms of emplacement and suggests a multiphase fracture-controlled injection.
**Keywords: Intrusion, Jurassic dolerite, Tasmania, emplacement.**

## INTRODUCTION

Jurassic dolerite intrusions of all scales, but usually very large, are topographically dominant and geologically ubiquitous across eastern and central Tasmania. Even though many features of the intrusions are well and commonly exposed, it is very rare to find sites or exposures where several characteristic features are present in restricted or accessible areas. Most descriptions of the intrusions and their form, and most theories of emplacement, draw upon a large number of occurrences, few of which are easily visited (for example, Leaman 1975, 1977, 1995, Banks *et al.* 1989). Further, detailed description of those sites is generally not available, and most comments about intrusions have been given in association with gravity surveys (McDougall & Stott 1961, Leaman 1972, 1990a, Leaman & Richardson 1981).

There are, however, four sites (fig. 1) where all of the critical features of dolerite intrusions can be inspected easily; these are Mt Nelson (Leaman 1975, 1976, 1978, 1995), Cape Surville (Leaman 1978, Gulline 1984), Single Hill (Leaman 1975, 1976, 1978, 1995) and Lynwood. Although no one site displays a full set of features, those selected display several aspects of the intrusions and the intrusion process, at all scales, in a small area. No other sites are known which offer this clarity and economy of inspection.

Each of these four sites and the intrusion features found therein are described below. Each is recommended for visitation. These notes are intended as both a guide to the features present and a discussion of their origin, and provide new observations or new interpretation in each case.

The intruded Permian and Triassic rocks are known as the Parmeener Supergroup (Clarke 1989). The lower part, Permian, may be divided into an upper and lower glaciomarine sequence, while the upper part, Triassic-(?)Lower Jurassic, is a terrestrial sequence.

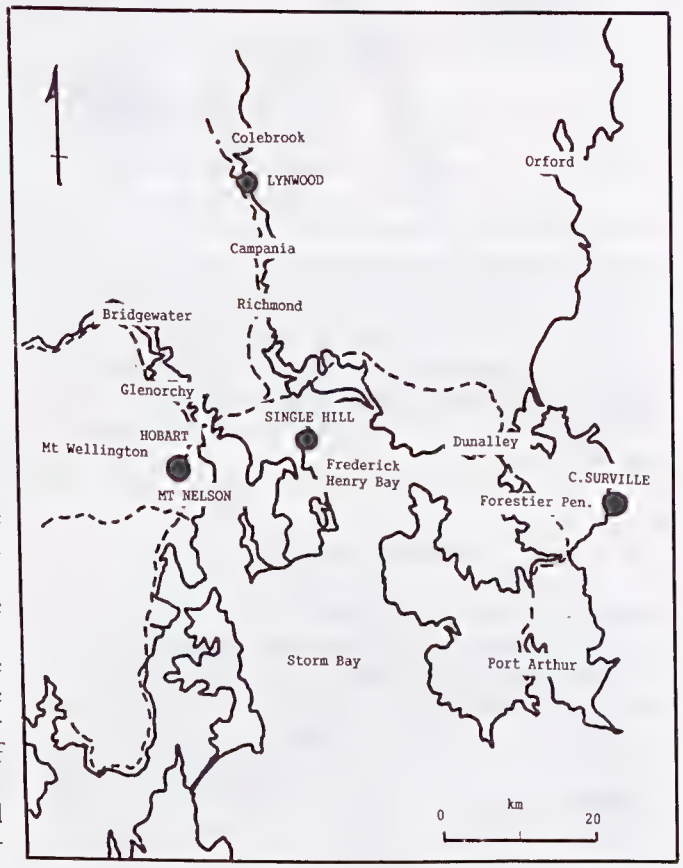


*FIG. 1 — Southeastern Tasmania showing the location of the selected sites. Cape Surville is the least accessible.*

## SITE 1: MT NELSON INTRUSION

The principal exposures are found beside the Southern Outlet near the Olinda Grove intersection and overpass 2 km south of Davey Street, Hobart. Accessory features are to be seen in and near the Waterworks Reserve, north of Tolmans Hill, and along the highway nearer Kingston (fig. 2).

All sites are accessible by car. The Hobart section of the *Tasmanian Towns Street Atlas* can be used to locate all roads. All the features of the Olinda Grove area can be inspected in less than two hours, but a full day is required to view the entire set of localities indicated.

Elements of this site have been partly illustrated by Leaman (1976, 1978) and discussed by Leaman (1995). The details of the relationships and exposures present have not been published previously.

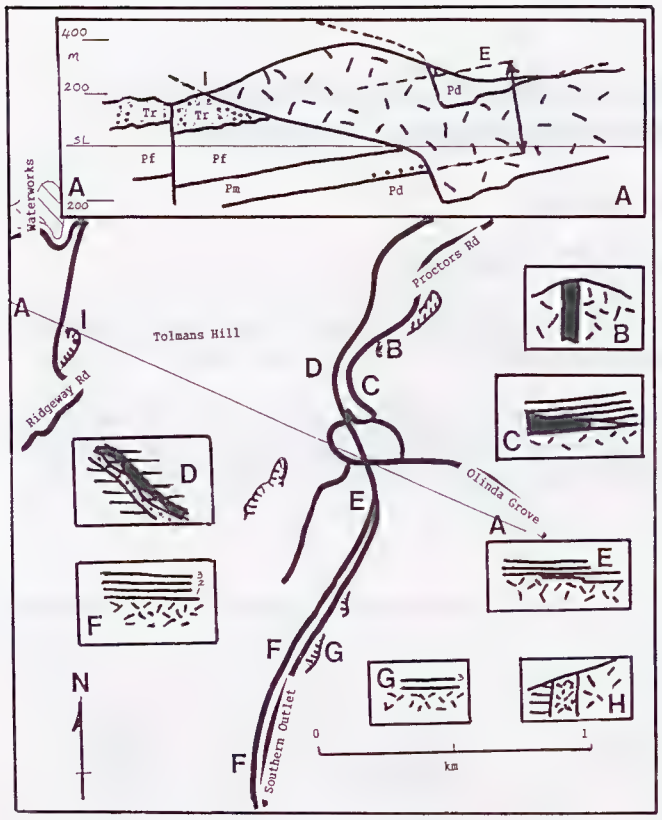


*FIG. 2 — Mt Nelson: Location of intrusive features in the region of Proctors Road, Olinda Grove and the Waterworks. The small, located sketches indicate the features present and the section suggests the regional character of the intrusion. Intruded rocks are shown with dotted or lined patterns; dolerite is shown in black or as random ticks in order to distinguish multiple intrusions.*

## Major Contacts

Immediately south of the overpass (E, fig. 2), the roof of a dolerite sheet steps from bed to bed through a fossiliferous, calcareous mudstone of Permian age (correlate of Deep Bay Formation, of Farmer 1985, Clarke 1989). Plate 21 in Leaman (1976) and plate 15 in Leaman (1978) show this feature. The overall effect is of low-angle transgression, since concordance is predominant. Sill character is always well displayed and leads to a mistaken view about the shape of large intrusions. The overall discordance of the Nelson intrusion in these exposures amounts to less than 1% of the thickness of the intrusion. The base of this intrusion is exposed several kilometres to the southeast, across Mt Nelson near upper Taroona, within the same formation. A regional dip of 5° and presumed absence of any large-scale faulting suggest an intrusion thickness of over 350 m.

Review of all contacts in the Olinda Grove area, however, indicates an average 10° rise in the top of the intrusion from west to east, compared with the regional dip of 5°. Thus, the intrusion has transgressed upward across the bedding from the west, with an average differential of 5°. This effect is relatively local, since other exposures up to 1 km south of Olinda Grove (F, G, fig. 2) display long concordant (sill-type) boundaries (e.g. pl. 20, Leaman 1976; pl. 14, Leaman 1978), some of which are consistent in level and dip, and others of which imply a transgression or fault offset between exposures. All transgression appears to be up from west to east. The section in figure 2 (near E) shows how the effective dip of the intrusion may exceed regional dips.

## Minor Contacts

North of the overpass the contact is multiply intruded (pl. 22, Leaman 1976), and one intrusion contains a frozen, bulbous nose within the wedge prised open by the magma (C, fig. 2; pl. 8, Leaman 1978). The tip of the wedge (shown unfilled in the diagram) is now filled with highly weathered material, which was probably a gas-enriched fluid containing rock or magma fragments at the time of injection. The apparent sense of injection is up from north to south, due to orientation of the cutting, but the real direction may have been WNW–ESE, based on three-dimensional review of all exposures and relationships. The frozen wedge of incomplete injection (black in diagram) is within the roof of the earlier, major intrusion (patterned). The hydraulic conditions which force this relationship have been discussed by Leaman (1975, 1990b). This is the only known magma wedge involving the Tasmanian dolerites (compare Mudge 1968). A quarry beside Proctors Road, directly below these exposures, contains a dyke (about 4 m thick) of glassy dolerite within very coarse- grained and commonly pegmatitic dolerite (B, fig. 2; Edwards 1942, Spry 1962). The upper part of this dyke appears across the highway in a now-filled quarry (D, fig. 2; pl. 23, Leaman 1976; pl. 7, Leaman 1978). Only the upper part of this intrusion is now visible there. Authorities seeking to restore such sites should seek advice about the conservation value of the contents! The dyke west of the road is composite, less than 2 m thick, and remnants of sedimentary contacts persist between two fine-grained dolerites. The margin of an earlier intrusion has been re-intruded in a manner comparable to that observed in the roof top near C (fig. 2).

Comparable compound margins may be found 5 km south of the overpass, where the major Mt Nelson intrusion has been faulted and the fault subsequently intruded (e.g. H, 525400E, 5243400N). The second intrusion is rarely more than 15 m wide and separates Permian siltstones from very coarse-grained dolerite. Neither sedimentary rock nor earlier dolerite is thermally affected in any significant manner. This contact extends N–S, whereas the main intrusion margin nearby trends approximately E–W.

## Internal Features

Systematic variations in texture can be found within the Tolmans Hill region (fig. 2) but no banding or layering has been recognised. This suggests that the main Mt Nelson intrusion was due to a single large magma pulse. This character is also true of the Mt Wellington intrusion, and the early petrological studies, such as those by Edwards (1942), which were based on both the Mt Nelson and Mt Wellington sheets, have led to assumptions about the differentiation and intrusion of dolerite bodies which are not universally applicable (contrast site 3, Single Hill).

The road cuttings south of the overpass (F, fig. 2) demonstrate the quality of the rock, its fresh colouring and the impact of subhorizontal jointing on water flow and weathering. There is little evidence of systematic, thermally

developed jointing parallel to the contacts in this intrusion, and the subhorizontal joints are due to relaxation. These extensive, large-scale joints always disrupt all other joint types, are slightly curved and occur at angles generally less than 15° to present average landform slopes but in the same sense. Elastic rebound from removed loading is implied. Other examples of this joint type can be seen in Ridgeway Road, above site I (fig. 2).

Exposures around Tolmans Hill display columnar joints with slightly curved faces up to 4 m across (e.g. I). Other, local jointing is imposed upon the columnar pattern, and the change from platy joints to large columns, whose long axes are normal to the margin of the intrusion in each case, can be seen in Waterworks Quarry near the contact (I). This contact dips south at about 20°. The joint relationships found near intrusion margins were described by Leaman (1978). Platy joints, or mini-columns, are not a universal feature of Tasmanian intrusions; they are pronounced in some areas and not others. The reason for this variation is not known but may be a function of dolerite intrusion stage, magma composition, country rock hydrology and heat transfer, or intrusion size. East Tasmanian dolerites, such as those north of Swansea and within the Fingal–St Marys region, are compositionally and texturally distinctive and regularly display platy joints well in from the margin (Leaman & Richardson 1981, Leaman 1978). Ambient temperatures may also have been important — factors which may be influenced by the presence and cooling of earlier intrusions or the ability of the intruded medium to conduct or transfer heat. Platy joints (or bow-tie, festoon or other complex patterns) are rarely seen where the rocks of the lower marine, Lower Parmeener Supergroup have been intruded, as at Mt Nelson.

Examples of the varied weathering style of Tasmanian dolerites and of the local instability associated with some conjunctions of thermal and tectonic joint orientations and road alignment may be found along Ridgeway Road. These provide good examples of the engineering issues involved. This road tends to wind up the hillside and cuttings along it tend to generate an array of face orientations with respect to the many joint sets displayed. Several of these combine, in some places, to face and dip toward the road. Large-scale collapse has occurred wherever weathering is also extreme, or has been influenced by one joint set — often the low-angle, elastic relaxation joints.

### Metamorphic Effects

The pebbly mudstone intruded by the dolerite has been metamorphosed, and the distinctive colour banding developed reflects slight variations in composition (especially calcareous content) and texture. Within a few metres of the contact, the rock has been converted into a calc-silicate hornfels, with generation of diopside and, in places, wollastonite. Marked metamorphic effects rarely extend more than 3 m from the roof contact, although lesser changes may be more extensive (compare B–D, fig. 4, Single Hill, below).

### Overall Intrusive Form

The base of the Mt Nelson intrusion lies within the Deep Bay Formation, at Taroona, and within Triassic rocks, on the northwest side of Tolmans Hill (I). The section (fig. 2) indicates that stratigraphic control within the Waterworks–Tolmans area is insufficient to establish the dilation across the intrusion within Tolmans Hill, but the units exposed are consistent with an intrusive thickness of about 350–400 m (for dilation rules, Leaman 1972).

Early analyses of the Mt Nelson intrusion placed a feeder system for the major sheet in the region near the axis of Mt Nelson (Leaman 1972, 1975). Subsequent gravity analyses linked with aeromagnetic data have shown, however, that the feeder system is large and located within the Ridgeway–West Tolmans area (Leaman 1990a, 1992, fig. 13). Granophyric differentiates of the dolerite in the Ridgeway area and many small intrusions in the Ridgeway and Proctors Road areas are consistent with a feeding centre there. The overall sense of magma passage is up from southwest to northeast. The three-dimensional relationships of the entire intrusion can be satisfied only by a fracture and intrusion rising in this manner.

## SITE 2: CAPE SURVILLE INTRUSION

The large dolerite intrusion at Cape Surville was, until recently, only visible from the sea but not readily accessible. It remains almost inaccessible to touch, but locations which allow visual appraisal can now be reached overland.

Cape Surville is the most easterly promontory of the Forestier Peninsula and overlooks some of the wildest sea-cliff coastline in Tasmania. The principal exposures, up to 300 m of vertical section on Deep Glen Bluff, are visible from the Cape (fig. 3).

Access to the site from vehicular roadheads requires a minimum walk of about one hour on good tracks,

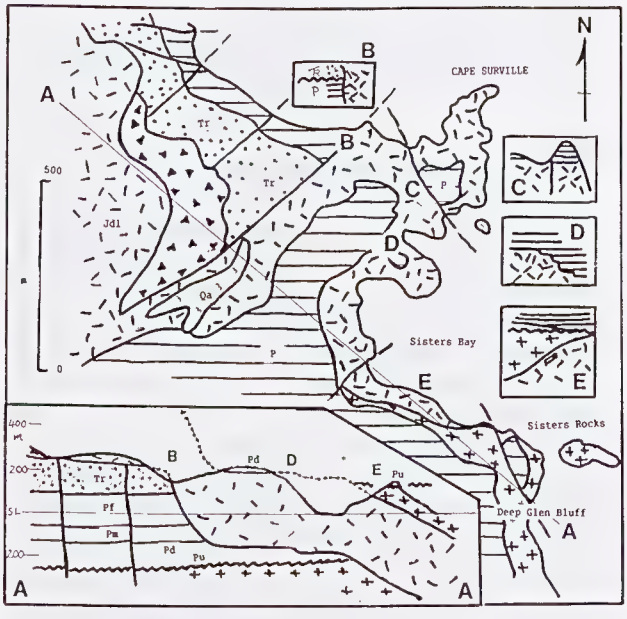


*FIG. 3 — Cape Surville: Location of intrusive features in the region of Cape Surville and Deep Glen Bluff. The small, located sketches suggest the features present and the section shows how these are related. The geological basemap is a complete revision of Gulline (1982). Dolerite is shown by a tick pattern, Devonian granites by a cross pattern, Triassic rocks by dots, Permian rocks by horizontal lines and Pleistocene talus by triangles.*

maintained by the Hobart Walking Club with the approval of Forestry Tasmania. The nearest roadhead for a car is at 576500E, 5243050N on Schofields Road, reached by Hylands-1 side road from Murdunna: a four-wheel-drive vehicle, using the same basic access, can reach 578950E, 5242100N (Tasmap 1:25 000 *Murdunna*). Allow an extra half-hour for the walk from the car terminus.

## Major Contacts

Cape Surville itself is composed largely of dolerite, with two small caps of Permian rocks (C, fig. 3; pl. 11, Gulline 1984) that include correlates of the Malbina Formation and Risdon Sandstone. Much more strongly bedded, calcareous, finer-grained formations underlie these units, but most can only be observed on a crestal "island" south of the cape (D, fig. 3). This is visible in the middle distance in plate 1. Dolerite transgresses through these finer-grained units in the manner described at Mt Nelson. Metamorphic and colour changes are also comparable in these calcareous and fossiliferous rocks, which are probable correlates of the Deep Bay Formation.

The principal intrusive feature in this area is exposed in the cliffs of the north face of Deep Glen Bluff. A smoothly curving dolerite sheet contact arcs upward from sea level, with an average dip of about 25°(E, fig. 3; pl. 1; pl. 21, Leaman 1978; pl. 10, Gulline 1984). From sea level to an elevation of about 120 m this intrusion is wholly within Devonian granite. Above this, the dolerite enters nearly horizontal Permian rocks. The almost-planar unconformity is well exposed. Although at least four granitoid variants are seen at Deep Glen Bluff, the principal exposure lies within adamellite.

The contact is nowhere disrupted and is not influenced by any subvertical jointing or faulting. Fractures which parallel the contact occur within the granite. The magma has clearly followed a fracture and the granite complex has reacted as a homogeneous medium.

## Minor Contacts

One aberration may be observed near the contact just below the unconformity. A trapezoidal block of granite no more than 3 m thick has been included in the intrusion (E, fig. 3). This parting of the intrusion to allow less than 2 m of dolerite above a block has been termed a xenolith (Leaman 1975), while the style of intrusion splitting has been termed a leaf of intrusion (Francis 1982, Leaman 1995). Since the roof contact has not provided the included block — there is no offset of the margin to allow keying of the inclusion — then the base must be the imperfect face. Since the fracturing and intrusion process is dynamic and subject to hydraulic constraints determined by viscosity and crystallisation, the splitting to form the leaf clearly occurred very early in the injection process. The first magma has passed above the block and the remainder is below it. The rapid chilling of such a thin intrusive split or leaf would have prohibited further injection near the margin. There is no evidence for multiple injection or layering in this intrusion, and the hydraulic interconnection of both rapidly cooling leaf and main intrusion mass has lifted the detached fragment. This well-displayed leaf is relatively small, when compared with the leaves described by Francis (1982) or McGregor & McGregor (1948). Other leaves are known (Blackmans Bay South, Banks *et al.* 1989: 376; Boyer south and Mt Direction, Leaman 1975).

*PLATE 1*
*View of Deep Glen Bluff and the Cape Surville intrusion. The smoothly curling contact of the roof within granite may be contrasted with the irregular transgressive forms within Permian rocks [foreground]. This view is from site C (fig. 3).*

## Overall Intrusive Form

The entire display is unique (pl. 1); it is possible to observe changes in intrusion style above and below the basin unconformity, with characters predicted by both Carey (1958) and Leaman (1975), although examples of the nature of the fracture could not be provided.

The Surville–Deep Glen Bluff intrusion also presents enough information to infer its thickness, even though the base is not exposed. Northeast of Cape Surville, the intrusion is terminated in a complex faulted contact (B, fig. 3). The post-intrusion fault displacement is small, probably no more than 15 m, and represents the offset on faults which separate Deep Glen Bluff and the Sisters Rocks. Similar small displacements (5–15 m) along the coastline north of Cape Surville disturb the virtually conformable boundary between Late Permian marine and Early Triassic terrestrial deposits.

It is possible, therefore, to match stratigraphic levels on each side of the intrusion quite closely; the basal Permian unconformity approximates the level of the basal Triassic disconformity. The dilation of the intrusion, or its thickness, equals that of the entire Permian sequence in this location. Since the Triassic disconformity lies about 350 m above the sub-Permian unconformity in the Deep Glen area then the intrusion must be about this thickness.

Possible inaccuracies in this estimate arise from small faults in the area - possibly about 10 m, variations in the total thickness of the Permian sequence west of Deep Glen Bluff — possibly 25 m, and any associated variations in the unconformity surface. This surface is irregular, as seen in Deep Glen Bluff (E, fig. 3), and does include at least one minor onlap to the unconformity and another within 15 m above it. The intrusion may be as thick as 385 m.

The intrusive sheet rises from ESE to WNW (at Deep Glen Bluff) and SSE to NNW (toward Cape Surville), before stepping upward and out of the Permian rocks just west of Cape Surville (in the style of Leaman 1975). This

indicates a feeder south of Sisters Rocks offshore. Gulline (1984) refers to the exposure within granite as the feeder. The stepped zone (B, fig. 3) is a faulted contact, but better access has permitted some revision of the mapping of Gulline (1982), and this is also shown in figure 3.

## SITE 3: SINGLE HILL INTRUSION

Single Hill is an isolated hill located between Lauderdale and Seven Mile Beach (fig. 4). A series of superb exposures of its eastern face is available along the shores of Frederick Henry Bay. The Hobart section of the *Tasmanian Towns Street Atlas* can be used to locate this site. As many of these exposures lie within the tidal range, and there is some active beach formation, some small intrusions and parts of the roof of the major intrusion are only exposed at low tide or after storm erosion. The site is very accessible, and inspection of its contents requires allocation of at least half a day.

### Major Contacts

The regional setting is that of the roof of a major intrusion with a steep elbow upward to the west, away from the coast and into the heart of the hill. The roof of the main intrusion is exposed. The northern side occurs north of a small fault (between 10 and 15 m displacement) at A (fig. 4), and to the south as a major dipping contact D–E (the elbow) parallel to a small sheet found in the cliff at B (i.e. approx. 50°N). This, coupled with the dyke extension pattern, indicates the overall stress field (N–S extension). Both lateral pillars of the intrusion, whether concordant top to the north or discordant arm to the south, reveal compound and multiple intrusion. The roof is subconcordant near A but is more irregular near G. A roughly triangular sectional wedge of Permian rocks has been preserved between the intrusion roof and the land surface (from C to E). The rocks within the intrusion roof were clearly stressed and fractured by tensile forces (see Minor Contacts below).

### Minor Contacts

Leaman (1975) described en-echelon dyke fingers extending from the main intrusion below, which indicate a horizontal extension, overall, of about 0.6 m within a zone 2 m wide. These fingers are located at D (fig. 4). These small dykes are very glassy, with thin (< 5 mm), irregular, protruding tips, which extend more than a metre as greenish veins.

A small intrusive sheet can be seen in the cliff nearby (B, fig. 4). This feature was illustrated in plates 24 and 25 in Leaman (1976) and provides the best single and complete example of dilation associated with a dolerite intrusion. Both horizontal and vertical dilation (approx. 90 and 170 mm respectively) can be defined. Beds, or intrusion wall irregularities, can be matched across the intrusion (pl. 24, Leaman 1976). The overall view (pl. 25, Leaman 1976) shows how the intrusion has arched upward following a fracture in these well-bedded rocks, which are correlates of the Deep Bay Formation. A large granite pebble has been split by the intrusion. The plate shows that a large piece of limestone has been included in the upper part of the intrusion. This fragment is much altered and may have been carried within the magma; it is not derived from any

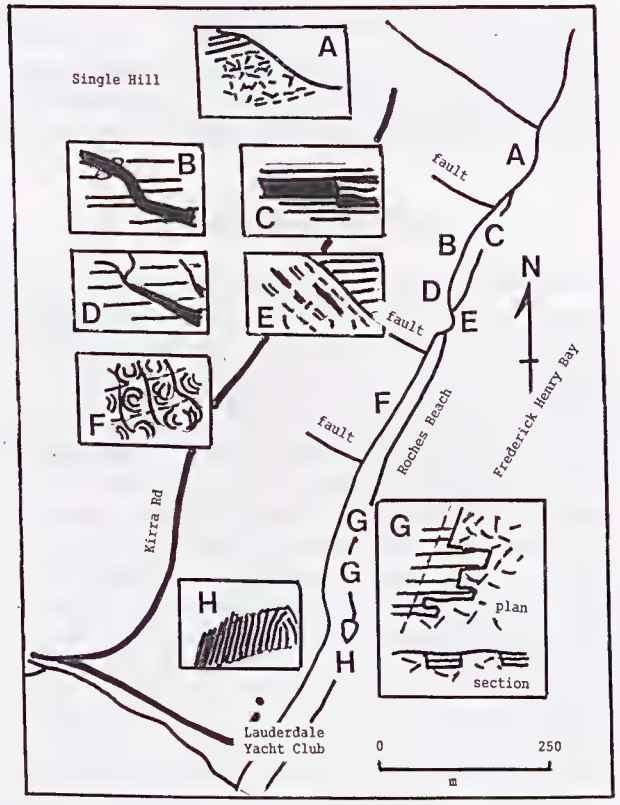


*FIG. 4 — Single Hill: Location of intrusive features in the Roches Beach–Single Hill area. The small, located sketches suggest the features present. Intruded rocks are shown with a lined pattern; dolerite is shown in black or as random ticks in order to distinguish multiple intrusions.*

part of the current exposure and does not have the form of a keyed leaf, since the overall thickness and dilation associated with the intrusion, including it, rather than of dolerite alone, are constant. This small sheet is one of many exposed in this area. Most others are thinner and much more concordant, but all display aspects typical of major sheets. One intrusion demonstrates that deformation may occur in the intruded rocks, where the intrusion changes shape abruptly (C, fig. 4); another shows that contemporaneous small faults — now almost entirely devoid of dolerite — did transfer dolerite to another level, and that these faults only apply to the units adjacent to the zone intruded. Beds above and below the intruded horizons are usually free of fracturing (C).

The complex character of the intrusion roof, within typical, more siliceous and thickly bedded Permian siltstones, is shown along the beach at G (fig. 4), mostly within the tidal range (average sea level dotted in figure). All contacts are subvertical, and there are variations in the elevation of the roof. Each zone is a subrectangular block. Jointing found near the contacts has a platy form, where the short axes are parallel to the roof and the long axis is normal to it. Some swirling character (curved, festoon and bow-tie joints) is often present (H, fig. 4), which may reflect block and roof corners or changes in elevation. Variations in thermal conditions were clearly important. This irregular roof effect has been observed in a strongly bedded, but otherwise homogeneous, lithology of the Fern Tree Group. The more concordant characters described

above are associated with the much more heterogeneous Deep Bay Formation.

Cooling columns of increasing size, which often display rounded faces or rounded corners, can be observed within the roof of the intrusion at A, E south and F (fig. 4).

### Internal Features

Marked layering parallel to the roof can be observed, irrespective of the attitude of the roof. The intruded dolerite in every case is normal contact zone fine-grained dolerite, while the layers contain coarse-grained material which is granophyric in composition (Everard in Leaman 1976). Many coarse layers have chilled margins, and the fracture patterns are also consistent with intrusion of granophyres into a crystallised but possibly warm main intrusion. The nature of contacts and texture is shown in plates 14 and 15 of Leaman (1976). The northern dolerite roof (A, fig. 4) contains numerous joints subparallel to the subconcordant roof contact, and this joint type, of thermal origin (Leaman 1978), may well have controlled later injection. Layering of the type exposed here, although involving less extreme differentiates, was first recorded in an intrusion drilled in Glenorchy (Leaman 1976). Similar layered dolerite has been observed in other areas (e.g. Cape Raoul, south of Port Arthur), but not all intrusions (compare Mt Nelson, Cape Surville) are "layered" or multiple. The layering is also apparent in the discordant elbow section of the intrusion at E, where the overall form is more irregular but essentially parallel to the margin.

### Metamorphic Effects

Different degrees of metamorphism may be observed in the roof at G and B–D (fig. 4). At G the intruded rock is a pebbly, siliceous siltstone, and hardening and joint formation is restricted to within about 0.6 m of the contact (horizontal or vertical). At B–C–D the intruded rock is a fossiliferous calcareous mudstone with beds of interspersed limestone. Diopside imparts a characteristic green colour, calcite in many fossils has been recrystallised, and wollastonite appears in the limier beds. Metamorphic effects extend up to 10 m from the roof of the main intrusion and are slightly more extreme than any observed at Mt Nelson.

The Single Hill site also contains fine examples of dolerite weathering, including spheroidal weathering with the release of large cobbles to the beach (F).

### Overall Intrusion Form

Faulting produces a sampling of the main intrusion. G–H (fig. 4) lie close to the intrusion roof and the rock is generally fine-grained. Some coarser layers may be found where outcrop permits. The fault block containing F is composed entirely of medium-coarse grained dolerite. There is no suggestion of layering or multiple intrusion, and the composition and texture indicate that F lies about 80–100 m below the roof of the intrusion. The dolerite at E is comparable to that at G–H but is a transgressive stage from the sheet roof beneath B-D. This roof is fully exposed at A.

## SITE 4: LYNWOOD INTRUSION

Lynwood homestead is located midway between Campania and Colebrook, along the Colebrook main road in the Coal River Valley, and built upon a rounded hill with thin brown soils and a glassy, platy-jointed dolerite, which intrudes the Upper Triassic Coal Measures. The landform is distinctive. A quarry beside the road allows inspection of part of the roof of the intrusion and the complex interior (Tasmap 1:25 000 map *Bains*, 533700E, 5285100N).

Bubble-shaped features have been recognised in the roof of those intrusions which were relatively close to the Jurassic surface. Most of these occur where faulting produced narrow grabens in a terrain resembling a basin-and-range province. The largest collection of these bubble-shaped features occurs in the Coal River Valley between Campania and northern Colebrook. Two have been quarried. All intrude Upper Parmeener Supergroup (Triassic–(?)Jurassic rocks) and their style was indicated by Leaman (1975, fig. 2). Apart from the bubble form — now reflected in rounded, bulbous hills with little soil cover — the heart of the bubble represents atypical dolerite. Jointing, of thermal origin, is very irregular and tangled, much as in the entablature of complex lava flows. The rock is fine-grained or glassy throughout and intensively veined with calcite, chlorite or zeolites. In normal intrusions, only major joints contain small amounts of these minerals but, in the bubbles, these minerals are common to dominant. Weathering is also extensive, and much travertine is present.

Other fine examples of this intrusive style occur on the south coast, at Lion Rock, and in the Derwent Valley, near Hamilton and Ouse.

## SUMMARY OF FEATURES

Table 1 indicates the range and type of features which can be observed at each site.

The table suggests that Single Hill offers the most complete single demonstration. It provides many fragmental pieces of evidence at all scales, and it is the only site to display large and small features. The small structures are complete. Although an array of joint types is exposed, some better examples of festoon and bow-tie joints occur elsewhere in Tasmania (east coast dolerites from Swansea to Douglas River, north coast dolerites near Devonport).

The most important site in terms of regional perspective and overall form of the large intrusions is at Cape Surville. It is the only place in the Tasmanian province where basement and cover relationships are visible in section and no inference is necessary. The intrusions displayed at the four sites constrain any intrusion theories. The Single Hill and Cape Surville intrusions show that injection followed a fracture, and the Mt Nelson intrusion shows that the fracture was wedged open by the magma. All intrusions show that bedding surfaces modified the form of the fracture. The intrusions at Single Hill and Mt Nelson were multiphase, with pronounced layering produced in the Single Hill intrusion. Later intrusions were controlled either by marginal fractures in the earlier intrusions or by the primary fracture. No change is stress field is indicated. All joints of thermal origin have orientations and frequencies which reflect either the shape of the intrusion margin or distance from it.

TABLE 1
Features observed at each site

| | Mt Nelson | Single Hill | Surville | Lynwood |
|---|---|---|---|---|
| *Intrusive forms* | | | | |
| complete intrusion | – | x | – | – |
| partial intrusion | x | x | x | x |
| intrusion leaf | – | x | x | – |
| injection nose | x | – | – | – |
| large intrusion | x | x | x | – |
| small intrusions | x | x | – | – |
| sill forms | x | x | x | – |
| transgressive forms | x | x | x | x |
| roof bubble | – | – | – | x |
| fracture control evidence | – | x | x | – |
| dilation evidence | x | x | x | – |
| contact deformation | – | x | – | – |
| within cover rocks | x | x | x | x |
| within basement | – | – | x | – |
| fault associations | – | x | x | – |
| *Other aspects* | | | | |
| multiple intrusion | x | x | – | x |
| layered intrusion | – | x | – | – |
| contact phenomena | x | x | – | x |
| metamorphic effects | x | x | – | x |
| range of composition | x | x | – | – |
| weathering character | x | x | – | x |
| jointing | | | | |
| thermal | x | x | x | x |
| platy | – | x | – | x |
| curled | – | x | – | x |
| columns | x | x | – | – |
| fracture fills | x | x | – | x |

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# THE CRUSTACEAN AND MOLLUSCAN FAUNA OF TASMANIAN SALTMARSHES

Alastair M.M. Richardson, Roy Swain and Vera Wong

(with four tables and six text-figures)

RICHARDSON, A.M.M., SWAIN, R. & WONG, V., 1997 (31:viii): The crustacean and molluscan fauna of Tasmanian saltmarshes. *Pap. Proc. R. Soc. Tasm.* 131: 21–30. ISSN 0080–4703. Department of Zoology, University of Tasmania, GPO Box 252-05, Hobart, Tasmania, Australia, Australia 7001 (AMMR, RS); and 8 Cedar Court, Glen Waverley, Victoria, Australia 3150 (VW).

The crustaceans and molluscs of 65 saltmarshes and brackish marshes around the coast of Tasmania and the major Bass Strait islands were surveyed. Over 50 species were collected, but only eight (three talitrid amphipods, one crab and four gastropods) were confined to saltmarshes; the typical saltmarsh assemblage consisted of two talitrid amphipods, three oniscoid isopods, two crabs, two prosobranch snails and two pulmonate snails. The greatest species richness was found in marshes from the southeast and the far northwest, where the most extensive saltmarshes have developed. Several undescribed talitrids were collected and the range of two coastal species was extended significantly. The native woodlouse *Plymophiloscia ulverstonensis* was commonly found on the upper parts of the marshes, as was the introduced slater *Porcellio scaber*. The burrowing grapsid crab *Helograpsus haswellianus* was common on the marshes, though it was replaced by the ocypodid *Heloecius cordiformis* in brackish marshes, and by another grapsid, *Paragrapsus gaimardii,* in the only marsh examined on King Island. The hymenosomatid crab *Amarinus paralacustris* was recorded from the state for the first time at Hendersons Lagoon. Amphibolid and ellobiid snails typified the molluscan fauna of the marshes. The introduced ellobiid *Phytia myosotis* appears to have a major disjunction in its distribution between the southeast and northern sites.

Tasmanian saltmarshes have a similar diversity of crustaceans and molluscs to those of New Zealand and South Africa. They are richer in species than saltmarshes of the northeast Atlantic coasts but have fewer crustaceans than the temperate east coast marshes of North America, and fewer molluscs than those of the coasts of the Pacific northwest.

**Keywords: salt marshes, diversity, Amphipoda, Isopoda, crabs, Gastropoda, Tasmania.**

## INTRODUCTION

Despite the ubiquity of saltmarshes in southern temperate Australia, their fauna has received surprisingly little attention. The only published work on the fauna of an Australasian saltmarsh (Paviour-Smith 1956) deals with a marsh in the South Island of New Zealand, while an unpublished thesis (Marsh 1982) describes the fauna of a saltmarsh on the Derwent River in southern Tasmania. The paper presented here describes the crustacean and molluscan fauna of saltmarshes around the coast of Tasmania and the major Bass Strait islands.

Saltmarshes are, by definition, areas bordering sheltered saline waters, vegetated by herbs, grasses or low shrubs. They are exposed to the air for most of the time but are subject to periodic flooding as a result of tidal or non-tidal fluctuation of the adjacent water body (Adam 1990). Tidal submergence distinguishes coastal saltmarshes from terrestrial habitats, and the absence of tall woody plants distinguishes saltmarshes from mangroves, the other major type of tidal vegetation (Adam 1990).

In many estuaries, there is a continuum between coastal, saline marshlands and marshlands in the upper estuary that are subject to tidal but non-saline flooding (Adam 1990), creating a problem of definition. In this study, the succulent ground-covering herb *Sarcocornia quinqueflora* was used to indicate saltmarsh, since it is restricted to wet and saline habitats not subjected to prolonged inundation (Waisel 1972); of all the saltmarsh species it is the most tolerant of high salinity (Patton 1942) and poor drainage (Kirkpatrick & Glasby 1981), and does not grow in water of low salinity. Nevertheless, a number of brackish marsh sites which lacked *S. quinqueflora* were included in this study, since their faunal communities differ both from those of true saltmarshes and from those of freshwater marshes (Odum 1988), and yet they represent part of the sea-to-land transition.

The Tasmanian coastline is diverse, ranging from the very exposed shores of the west coast to the dissected, sheltered coastline of the southeast. There are several large marine inlets, Macquarie Harbour, Port Davey/Bathurst Harbour and the Derwent and Tamar estuaries. Saltmarshes have developed in a variety of sheltered locations in Tasmania; they range in size from sites of many hectares, extending along kilometres of shoreline, to narrow bands a few hundred metres long or less. The flooded river valleys and estuaries of the Bass Strait and east coasts support significant areas of saltmarsh, but the sheltered shores of the indented south east coast and the far west of the north coast support the largest areas. On the west and south west coast, the major inlets of Macquarie Harbour and Port Davey/Bathurst Harbour provide sheltered conditions, and saltmarshes have formed there. True saltmarshes do not occur on high energy coasts, but similar plant communities can be found where saltwater accumulates along rocky coasts, as a result of spray or occasional inundation by the sea (Kirkpatrick & Glasby 1981). One such community on the west coast was examined in this study.

The fauna of saltmarshes can be divided into four major ecological groups: marine, freshwater, semiterrestrial and terrestrial (Adam 1990). When the aquatic species, which have a much wider habitat range than the water in and around saltmarshes, are eliminated, the species which remain are those that inhabit the marsh surface (Daiber 1977); it was these species that we chose to sample in this survey. Crustaceans and molluscs dominate this fauna, and they are likely to be the most important groups in these decomposition-based systems. Marsh (1982) found that the dominant saltmarsh animals in southeast Tasmania were crabs, gastropods, coccid Hemiptera and mites. All

these groups can be considered important by reason of their abundance or biomass (Subrahmanyam *et al.* 1976), but herbivorous insects are unlikely to play a major role in the marsh ecosystem, since levels of herbivory in saltmarshes are low (Teal 1962), probably because of the poor nutritional status of the vegetation (Adam 1990). In contrast, detritivores are of considerable importance in energy and nutrient flows (Adam 1990) and in structuring the saltmarsh environment through their burrows (Marsh 1982). Thus, we chose to survey snails, amphipods, isopods and crabs as the most abundant and important components of the terrestrial fauna. These elements of the fauna also have the advantage of being available to be surveyed at all seasons of the year.

In this paper, we describe the crustacean and molluscan fauna of Tasmanian saltmarshes and record the distribution of the species in these groups. While the distribution of the molluscan fauna has received some incidental attention (Smith & Kershaw 1981), the intertidal crustacean assemblages are almost entirely unstudied. Griffin (1971) described the ecological ranges of the crabs of southeast Tasmania, Richardson & Marsh (in press) described the ecological ranges of talitrid amphipods at Lutregala Marsh on Bruny Island, and some ecological and distributional notes were provided in the taxonomic studies of the oniscoid isopods by Green (1961).

## METHODS

In order to cover as wide a range of habitats as possible, our sampling regime was based on the vegetation communities in each marsh, because these represent plant species assemblages, which in turn reflect the soil conditions, i.e. salinity and drainage (Kirkpatrick & Glasby 1981, Partridge & Wilson 1989). Saltmarshes have been traditionally viewed as having three zones between sea and land (Adam 1990): the low marsh — the area which is inundated by every tide; the mid marsh — the area which is inundated by most tides; and the high marsh —the area which is very rarely inundated. These three zones do not have distinct boundaries but usually can be distinguished by a change in the vegetation community or its understorey. Within each saltmarsh zone, we identified three broad vegetation types:

(1) a ground-covering succulent and herbaceous community, characterised by *Sarcocornia quinqueflora, Samolus repens, Hemichroa pentandra, Selliera radicans, Wilsonia backhousei, Sarcocornia blackiana* and *Pucciniella stricta;*
(2) a salt bush community, characterised by *Arthrocnemum arbuscula;* and
(3) a grass/sedgeland community, characterised by *Stipa stipoides, Poa labillardieri, Juncus krausii* and/or *Gahnia filum, Leptocarpus brownii,* or *Spartina townsendii.*

Some saltmarsh plants extend over more than one of these tidal zones. *Sarcocornia quinqueflora,* for example, is able to grow in all three. This system of plant community classification encompasses all the vegetation communities defined by Kirkpatrick & Glasby (1981). We sampled four replicate quadrats from each vegetation community within each of the three zones defined above. In the marsh mid-zone, there were sometimes two distinctly different grass/sedge communities, most commonly dominated by *Gahnia filum* or *Stipa stipoides,* reflecting different soil conditions (Kirkpatrick & Glasby 1981) and having different morphologies. In such cases, both communities were sampled independently.

In each vegetation zone, quadrats were located so that the samples represented a range of heights within the category and zone, and encompassed the whole range of plant species within the vegetation community. The quadrats were 0.5 x 0.5 $m^2$ in area, and from each one amphipods, isopods and snails were collected by hand or with an aspirator, then preserved in 70% alcohol. An estimate of the total numbers of individuals of each species was made and the number of crab burrows (i.e. burrow systems, not burrow openings) was recorded. In order to find as many of the species present in each quadrat as possible, the vegetation was thoroughly searched, which often involved teasing apart grass tussocks, pulling up plants at the roots (since amphipods sometimes follow these down into the soil) and overturning mosses and logs. Crabs were sampled by digging up a number of burrows within a quadrat and from mudflats within the saltmarshes.

The size of quadrats used was a compromise necessitated by the wide range in the size and abundance of the species being sampled. Because they were stratified by vegetation type, the number of quadrats sampled at each site depended on the complexity of the vegetation, and ranged from four (Granville Harbour, Policemans Point, New River North) to 24 (Stanley West Inlet). Species accumulation curves for the data from Stanley West Inlet, where 24 quadrats were collected, showed that, even in the worst case, 90% of species were collected after 12 quadrats had been examined. Seventeen sites were sampled with 8 quadrats or fewer, so it is possible that the species richness at those sites may have been underestimated.

The animals collected were identified, using the following resources: amphipods — A.M.M. Richardson (unpublished key); terrestrial molluscs — Smith & Kershaw (1981); marine molluscs — Macpherson & Gabriel (1962) (nomenclature follows changes published in the *Zoological Catalogue of Australia* (Smith 1992)); isopods — Green (1961) and Hopkin (1991); crabs — Campbell and Griffin (1966) and Westcott (1976).

## RESULTS

In total, 65 marshes were investigated, 52 of which were saltmarshes, the rest being brackish marshes or at the mouths of rivers. Figure 1 shows the locations of the sample sites.

Over 50 species of crustaceans and molluscs were collected, but only eight of these have distributions that are effectively confined to saltmarshes: the amphipods *Eorchestia palustris* and two undescribed *Eorchestia spp.*, the snails *Ophicardelus ornata, Salinator solida, Phytia myosotis* and *Hydrococcus brazieri,* and the crab *Helograpsus haswellianus.* The most common crustaceans and molluscs in Tasmanian saltmarshes are the marsh-hopper *Eorchestia palustris* and the beachflea *Orchestia australis,* the snails *Salinator solida, Ophicardelus ornata, Hydrococcus brazieri* and *Tatea rufilabris,* the isopods *Ligia australiensis, Deto marina* and *Porcellio scaber,* and the crabs *Helograpsus haswellianus* and *Paragrapsus gaimardii.*

The saltmarshes with the greatest diversity of crustaceans and molluscs were Hildyard Point, in Blackman Bay on the east coast (19 species), Lauderdale, in the Derwent estuary (17 species), Long Point, on the west coast of

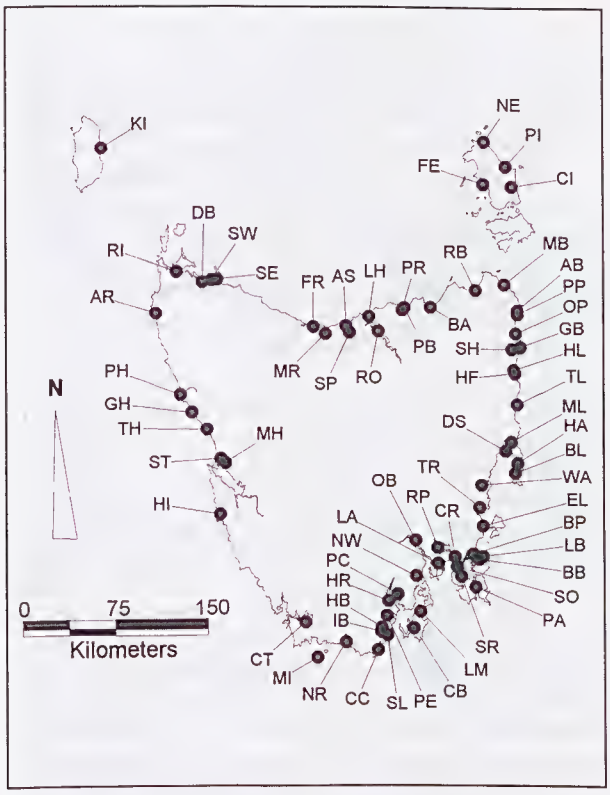


*FIG. 1 — Location of sampling sites. Site codes are as follows. AB – Ansons Bay, north side; AR – Arthur River, marsh near mouth; AS – Asbestos National Park; BA – Andersons Bay, Trent Water; BB – Blackman Bay, Forestier Peninsula; BL – Bryans Lagoon, Freycinet Peninsula; BP – Hildyard Point, Blackman Bay; CB – Cloudy Bay Lagoon, Bruny Island; CC – Cockle Creek; CI – Cameron Inlet, Flinders Island; CR – Carlton River; CT – Celery Top Island, Bathurst Harbour; DB – Duck Bay, Smithton; DS – Dolphin Sands Road, Moulting Lagoon; EL – Earlham Lagoon; FE – Long Point, Flinders Island; FR – Forth River; GB – Georges Bay; GH – Granville Harbour; HA – Hazards Lagoon, Freycinet Peninsula; HB – Hastings Bay, Southport; HF – Hendersons Lagoon, Falmouth; HI – Hibbs Lagoon; HL – Hendersons Lagoon, Scamander; HR – Huon River, Surges Bay; IB – Ida Bay, Southport; KI – King Island, Sea Elephant River; LA – Lauderdale, Ralphs Bay; LB – Swan Lagoon, Tasman Peninsula; LH – Low Head, Tamar River; LM – Lutregala Marsh, Bruny Island; MB – Musselroe Bay; MH – Macquarie Harbour; MI – Maatsuyker Island; ML – Moulting Lagoon, road to Coles Bay; MR – Mersey River; NE – Northeast River, Flinders Island; NR – New River Lagoon; NW – North West Bay; OB – Old Beach, Derwent River; OP – Sloop Lagoon; PA – Port Arthur; PB – Pipers Brook, Pipers River; PC – Port Cygnet; PE – Port Esperance; PH – Pieman Heads; PI – Patriarch Inlet, Flinders Island; PP – Policemans Point, Ansons Bay; PR – Pipers River; RB – Ringarooma Bay; RI – Coast opposite Robbins Island; RO – Rowella, Tamar River; RP – Railway Point, Pittwater; SE – Stanley, East Inlet; SH – St. Helens; SL – Southport Lagoon; SO – Sloping Lagoon; SP – Port Sorell, south east arm; SR – Saltwater River; ST – Strahan; SW – Stanley, West Inlet; TH – Trial Harbour; TL – Templestowe Lagoon; TR – Triabunna; WA – Little Swanport.*

Flinders Island (15 species), Lutregala Marsh, on the Bruny Island isthmus (15 species), a marsh in the far northwest opposite Robbins Island (15 species) and West Inlet at Stanley (15 species).

Analysis of the species richness at each site (fig. 2) shows that the richest sites are generally in the indented coastline of the southeast, in the inlets of the north coast, or in the far northwest. The west coast, in contrast, has only two sites with five or more species.

The distribution and abundance of species in each of the major groups is discussed below.

## Amphipoda

The Talitridae is the only family of terrestrial amphipods; 20 described or undescribed species from this family were collected, though some were very rare (table 1). The taxonomy of the intertidal talitrids is unsatisfactory, and few species from what is apparently a diverse fauna have so far been described (Richardson 1993, 1996). Because of this, informal names have been used for undescribed species or where generic placements are uncertain; formal taxonomic descriptions of these species are being prepared (Richardson, pers. obs.). Species have also been classified into Bousfield's (1982) and Friend's (1987) loose phylogenetic or ecological groupings: i.e. the marsh hoppers — plesiomorphic forms found in the wettest saltmarsh habitats; beachfleas — non-substrate-modifying species which are found on most muddy

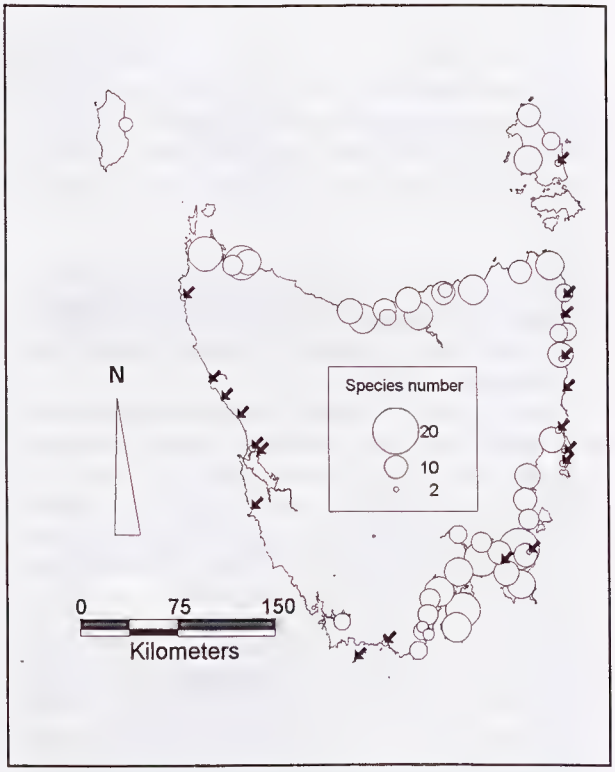


*FIG. 2 — Species richness in the saltmarshes. The sizes of the circles are proportional to the number of species collected at each site. Arrows mark sites where fewer than five species were collected.*

TABLE 1
Talitrid amphipods collected from Tasmanian saltmarshes

| Morphological groupings (after Bousfield 1984)* | Ecological Groupings (after Friend 1987)* |
|---|---|
| Group 1a (palustrals) | |
| *Eorchestia palustris* Richardson, 1993 | Marsh-hopper |
| *E. rupestris* Richardson, 1993 | Marsh-hopper |
| *E.* n.sp. 1 Earlham Lagoon | Marsh-hopper |
| *E.* n.sp. 2 Rowalla | Marsh-hopper |
| *E.* n.sp. 3 Flinders West Coast | Marsh-hopper |
| Group 2 (beachfleas) | |
| *Orchestia australis* Fearn-Wannan, 1968 | Beachflea |
| *Transorchestia* "Lunawanna" | Beachflea |
| "4-dentate beachflea" | Beachflea |
| "4-dentate beachflea Old Beach" | Beachflea |
| "4-dentate beachflea Granville Harbour" | Beachflea |
| Group 3 (sandhoppers) | |
| not recorded from saltmarshes | |
| Group 4a (cuspidactylate landhoppers) | |
| *Tasmanorchestia* n.sp. 3 | Coastal landhopper |
| *Tasmanorchestia* n.sp. 5 | Coastal landhopper |
| Group 4b (simplidactylate landhoppers) | |
| *Austrotroides maritimus* Friend, 1987 | Coastal landhopper |
| *Austrotroides* n.sp. | Coastal landhopper |
| *Mysticotalitrus tasmaniae* (Ruffo, 1949) | Forest landhopper |
| *M. cryptus* Friend, 1987 | Forest landhopper |
| *Arcitalitrus bassianus* Friend, 1987 | Coastal landhopper |
| *Keratroides vulgaris* (Friend, 1979) | Forest landhopper |
| *K. pyrensis* Friend, 1987 | Forest landhopper |
| *K. rex* Friend, 1987 | Coastal landhopper |

*Classified by Bousfield's informal scheme (Bousfield 1984) and Friend's ecological groups (Friend 1987).Work is in progress to describe the informally named species (beachfleas and marsh-hoppers – A.M.M. Richardson; landhoppers – J.A. Friend).

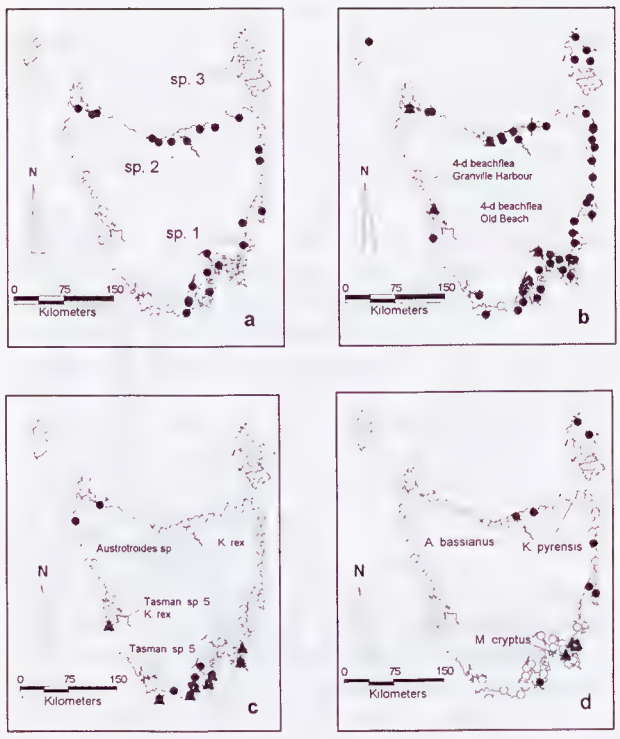


*FIG. 3A–D — Distribution of amphipods on Tasmanian saltmarshes. Collecting sites are marked by open circles. (A) Marsh-hoppers. Closed circles* – Eorchestia palustris; *crosses* – E. rupestris. *(B) Beachfleas. Closed circles* – Orchestia australis; *triangles* – Transorchestia *"Lunawanna"; crosses – "4-dentate beachflea". (C) Coastal landhoppers. Closed circles* – Tasmanorchestia *n.sp. 3; triangles* – Austrotroides maritimus. *(D) Forest landhoppers. Closed circles* – Keratroides vulgaris; *triangles* – Mysticotalitrus tasmaniae.

and rocky shores; and landhoppers — truly terrestrial species, which can be divided ecologically into coastal species, restricted to a zone close to the high water mark, and forest species, which extend hundreds of kilometres inland and to high altitudes.

Apart from one landhopper, *Arcitalitrus bassianus,* and one beachflea, *Orchestia australis,* all the described species of amphipods were Tasmanian endemics, but it will not be possible to make a complete assessment of the endemicity of the Tasmanian talitrid fauna until the fauna of south east Australia as a whole is better known. The distributions of these species are shown in figure 3A–D.

The marsh-hoppers (fig. 3A) are the only amphipods that are largely restricted to salt and estuarine marshes, although one marsh-hopper, *Eorchestia rupestris,* is also found on sheltered rocky shores on the east coast (Richardson 1993). Species in the genus have an almost statewide distribution and *E. palustris* is common in saltmarshes on all but the west and south coasts; it was not collected on Flinders or King Island. *Eorchestia* spp. are only found in areas of the saltmarshes that are subjected to regular tidal submergence, but their distribution on the marshes may include the lower emergent regions, where they overlap with the beachflea, *Orchestia australis,* which occupies the mid and upper, less-frequently inundated, areas. Cockle Creek was the only site where *E. palustris* co-occurred with both *O. australis* and coastal landhoppers. In the saltmarshes at Duck Bay, Ringarooma Bay, Hastings Bay, Huon River, Forth River, Ida Bay, Hendersons Lagoon (Scamander) and St Helens, *Eorchestia* spp. were the only supralittoral talitrids present. These sites are all reedy, submergent marshes, where the entire marsh is subjected to very regular inundation, and they are located at the heads of marine inlets and estuaries.

Of the two described species of *Eorchestia,* the small marsh-hopper *E. palustris* is widespread but apparently absent from the Tasman Peninsula, where *E. rupestris,* a larger marsh-hopper, is found in saltmarshes. The distribution of *E. rupestris,* as recorded in this study, appears to be very disjunct. It was found in southeast Tasmania from Lauderdale and Blackman Bay, and also from the saltmarsh on the west coast of Flinders Island, but it is also found on sheltered rocky shores between these localities (Richardson 1993).

Three undescribed forms of *Eorchestia* were collected, from three separate localities: the west coast of Flinders Island, Earlham Lagoon, and Rowella on the Tamar River. From each of these localities only very small numbers of individuals were found, and they co-occurred with much larger numbers of *E. palustris.*

The beachflea *Orchestia australis* is the most numerous and common amphipod in saltmarshes in Tasmania

(fig. 3B). It was found at 46 of the 52 saltmarsh sites on all coasts and occupies a wide range of habitats from the lower marsh to the landward reaches. It is also found in many other supralittoral habitats. At five sites (northwest coast opposite Robbins Island, Low Head, Pipers River, Bryans Lagoon and Southport Lagoon), it co-occurs with a four-dentate beachflea that is apparently morphologically identical except for the dentition of its left mandibular lacinia mobilis, a character of considerable phylogenetic significance (Bousfield 1982). Two other undescribed four-dentate beachfleas were found, one in the marsh-like vegetation above the rock platforms at Granville Harbour and the other in the estuarine marsh at Old Beach (a single individual only).

The beachflea *Transorchestia* "Lunawanna" is distributed patchily around the state. It is found in the Derwent and Huon Rivers, on Bruny Island, at Strahan, in the Forth River and on the northwest coast opposite Robbins Island. Although this distribution appears to be disjunct, it merely reflects the species' presence in other non-saltmarsh habitats (A.M.M. Richardson, pers. obs.).

The other amphipods found in Tasmanian saltmarshes are landhoppers of either the coastal (fig. 3C) or forest (fig. 3D) groups of Friend (1987). They are found in the upper marsh regions, areas which are rarely inundated, and a habitat that is essentially terrestrial, rather than intertidal or supralittoral. The coastal landhoppers *Austrotroides maritimus* and *Tasmanorchestia* spp. were restricted to the west, south and southeast coast. The other coastal landhopper collected, *Keratroides rex*, appeared in samples from only two localities, Hibbs Bay and Musselroe River, though it has been widely collected in non-marsh coastal habitats from South East Cape west to the Tamar River (Friend 1987). Of the forest landhoppers, *Mysticotalitrus tasmaniae* was found only on the Tasman Peninsula and at Blackman Bay. Landhoppers occurred in large numbers on the marshes at Cockle Creek, Port Esperance, Cloudy Bay, Port Arthur, Celery Top Island, Southport Lagoon, Hildyard Point, Saltwater River and Lutregala Marsh. Most of these sites are from relatively high rainfall areas with mostly undisturbed forest inland of the saltmarsh, except for Port Esperance and Saltwater River, where the backing vegetation has been largely cleared away for roads.

These collections significantly extend the ranges of some of the coastal landhoppers. *Tasmanorchestia* is now known not only from the west coast (Friend 1987), Bruny Island (Mulcahy 1990) and the northwest (Richardson *et al.* 1990), but also from the southeast and Tasman Peninsula. Mulcahy's records of *Austrotroides maritimus* (1990) from Bruny Island are confirmed and extended, while the range of *Keratroides rex* is extended from west of the Tamar (Friend 1987) to the far northeast at Musselroe Bay.

## Isopoda

Eight species of isopod were collected from the saltmarshes sampled (table 2). All occur in other habitat types as well as saltmarsh (Green 1974). *Cubaris tamarensis, C. sulcifrons* and *Plymophiloscia ulverstonensis* are endemic to Tasmania (Green 1974), but *Ligia australiensis* and *Deto marina* are also found elsewhere in Australia. *Armidillidium vulgare* and *Porcellio scaber* are both introduced species, originating in the Mediterranean and the Atlantic region of Europe respectively (Green 1974).

Figure 4A–C shows the distributions of all these species in Tasmanian saltmarshes. Of the intertidal isopods (fig. 4A), *Ligia australiensis* is found principally on rocky shores; however, it occurs in saltmarshes on the north, east and south coasts, and on the Bass Strait islands. It does not

TABLE 2
**Isopods collected from Tasmanian saltmarshes**

Family LIGIIDAE
*Ligia australiensis* Dana, 1853
Family STYLONISCIDAE
*Styloniscus* sp.
Family ONISCIDAE
Scyphacinae
*Deto marina* (Chilton, 1884)
Philoscinae
*Plymophiloscia ulverstonensis* Green, 1961
Family ARMADILLIDAE
*Cubaris sulcifrons* Green, 1961
*Cubaris tamarensis* Green, 1961
Family PORCELLIONIDAE
**Porcellio scaber* Latreille, 1804
Family ARMADILLIDIIDAE
**Armadillium vulgare* (Latreille, 1804)

* Introduced species.

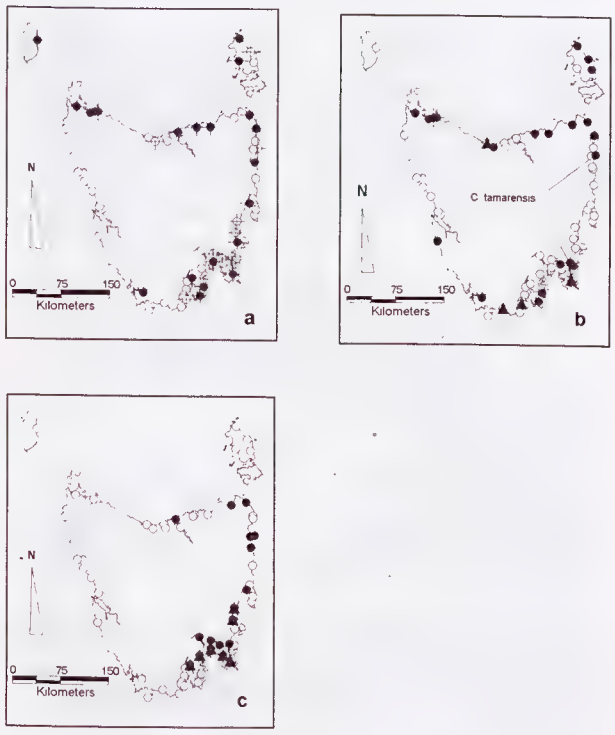


*FIG. 4A–C — Distribution of oniscoid isopods on Tasmanian saltmarshes. Collecting sites are marked by open circles. (A) Sea slaters. Closed circles* – Ligia australis; *crosses* – Deto marina. *(B) Coastal slaters. Closed circles* – Plymophiloscia ulverstonensis; *triangles* – Styloniscus *sp.; crosses* – Cubaris sulcifrons. *(C) Introduced slaters. Closed circles* – Porcellio scaber; *triangles* – Armidillidium vulgare.

occur at the inlet sites, except at Bathurst Harbour. *Deto marina* has a similar distribution to *L. australiensis,* but occurs more often in sheltered inlets. *D. marina* appears to be the isopod that is best adapted to life in Tasmanian saltmarshes, as it is the only species that is distributed throughout the mid-marsh flat.

Among the native woodlice (fig. 4B), *Plymophiloscia ulverstonensis* is widely distributed, while the other native *Cubaris* and *Styloniscus* spp. occur patchily in saltmarshes. These species are all terrestrial woodlice, though some are apparently confined to the maritime zone (Green 1961). As in the landhoppers, some species of woodlice are known to have distributions closely tied to the coastline (Sutton & Harding 1989, Hopkin 1991). It is likely that some of the woodlice collected in this study, e.g. *P. ulverstonensis* and the two *Cubaris* spp., have similar coastal distributions.

One of the introduced species, *Armidillidium vulgare,* is restricted to saltmarshes in the southeast, which may reflect its spread from a point of introduction in Hobart (fig. 4C). The other introduced species, *P. scaber,* is widely distributed on the east and north east coasts.

## Crabs

The nine species of crabs collected are listed in table 3, and their distributions in saltmarshes are shown in figure 5A–B. All these species of crab have been found in this habitat type previously (Griffin 1971). Although Griffin (1971) examined the local distributions of crabs in southeastern Tasmania in some detail, no statewide examination of the distribution of intertidal crab species appears to have been made.

*Helograpsus haswellianus* is the most common saltmarsh crab, but appears to be absent from the west coast and King Island (fig. 5A). It is often found over the entire marsh, in low, medium and high zones, living in complex burrows, which descend to the water table, and often have more than one entrance. The burrow density is greater in the lower and more frequently inundated marsh regions. Young individuals of *H. haswellianus* were found in the lower marsh and frontal mudflat areas. This species was not found on the most emergent or dry saltmarshes.

The second most common species, *Paragrapsus gaimardii,* is found all around the state (though it was not collected on Flinders Island), in the lower regions of the marsh and on the edge of creeks. In some instances, it is found in the mid regions of the marsh, but the more common species here is *H. haswellianus.* At one site (Sea Elephant River on King Is.) where *H. haswellianus* is absent, burrows of *P. gaimardii* cover the whole marsh area in a very complex and extensive network, similar to that found on the marshes dominated by *H. haswellianus.*

*Heloecius cordiformis* is found in the more brackish marshes. Griffin (1971) examined the habitat preferences of all species of Tasmanian grapsid and ocypodid crabs, and found, in laboratory experiments, that *H. cordiformis* has the least tendency to emigrate from freshwater to seawater. It lives on tidal mudflats in front of and interspersed throughout the saltmarsh. In these mudflats it co-exists in much greater density with *H. haswellianus.* The other crab species occurred in lower numbers in the low and frontal marsh areas.

The hymenosomatid genus *Amarinus* was collected from five localities (Fig. 5B). Material from all but one of these could be identified as *A. lacustris.* A single specimen from Hendersons Lagoon had the smaller female genital aperture and egg size that Lucas (1980) describes as characteristic of *A. paralacustris.* This species has not previously been recorded from Tasmania.

**TABLE 3**
**Crabs collected from Tasmanian saltmarshes, with their common names, where available**

| | |
|---|---|
| Family GRAPSIDAE | |
| *Brachynotus spinosus* (H. Milne-Edwards, 1853) | Little shore crab |
| *Cyclograpsus granulosus* (H. Milne-Edwards, 1853) | Smooth shore crab |
| *C. audouinii* H. Milne-Edwards, 1837 | |
| *Paragrapus gaimardii* (H. Milne-Edwards, 1837) | Mottled shore crab |
| *P. laevis* (Dana, 1852) | |
| *Helograpsus haswellianus* (Whitelegge, 1889) | Mud crab |
| Family OCYPODIDAE | |
| *Heloecius cordiformis* (H. Milne-Edwards, 1837) | Semaphore crab |
| Family HYMENOSOMATIDAE | |
| *Amarinus lacustris* (Chilton, 1882) | |
| *A. paralacustris* (Lucas, 1970) | |

## Mollusca

Gastropods were the most common molluscs found in Tasmanian saltmarshes. Twenty one species of snails and slugs were collected, and one species of bivalve (*Mytilus* sp.). The species collected are listed in table 4 and their distributions are shown in figure 6A–D.

Figure 6A shows the distribution of the three commonest prosobranch species, *Hydrococcus brazieri, Tatea rufilabris* and *Bembicium* sp. These species are widely distributed except on the west coast and King Island; all are found in other saline habitats. Our collections fill in the range of *Hydrococcus brazieri* in the east of the state, compared to

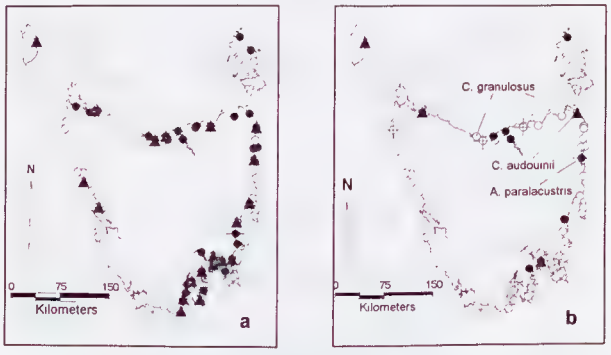


*FIG. 5A–B — Distribution of crabs on Tasmanian saltmarshes. Collecting sites are marked by open circles. (A) Common crabs. Closed circles* – Helograpsus haswellianus; *triangles* – Paragrapsus gaimardii; *crosses* – Heloecius cordiformis. *(B) Less-common crabs. Closed circles* – Paragrapsus laevis; *triangles* – Brachynotus spinosus; *crosses* – Amarinus lacustris.

Smith and Kershaw's records (1981), and extend its Tasmanian range to include Flinders Island. Our records extend the known range of *T. rufilabris* into the far northwest, but this species did not appear in our collections from Macquarie Harbour (cf. Smith & Kershaw 1981). *Truncatella scalarina* and, hence, the Family Truncatellidae is now known from the southeast of the state at Blackman Bay and Carlton River, rather than being restricted to the north coast (Smith & Kershaw 1981). Other prosobranch molluscs were collected (fig. 6B)and, at the seaward edges of saltmarshes, marine prosobranchs such as *Austrocochlea* spp. and terebrids often occurred.

Amphibious pulmonates in the families Ellobiidae, *Ophicardelus ornata* and *Phytia myosotis*, and Amphibolidae, *Salinator solida*, are highly characteristic of Tasmanian saltmarshes (Figure 6C). *Ophicardelus ornata* is found all around the state, apart from the west coast. Our records of it are apparently the first from Flinders Island. Its absence from the Derwent River region (represented by the Old Beach and Lauderdale sites), which would seem to be suitable habitat, is surprising. This species has a marsh-wide distribution, ranging from the submergent *Sarcocornia*- and *Juncus*-dominated vegetation, through the mid marsh into the more terrestrial reed/grass vegetation; it often shows a very clumped distribution pattern. Our records of the disjunct distribution of the Mediterranean and Eastern Atlantic species *Phytia myosotis* parallel those of Smith & Kershaw (1981) almost exactly (Stanley, central north coast, Flinders Island and Storm Bay). Climo (1982) suggests that this species was dispersed as egg capsules deposited on the hulls of wooden boats or on deck cargo that had come in contact with the saltmarsh fauna. Since these opportunities have become much rarer with the advent of steel hulls and constructed harbours, the present distribution of *P. myosotis* may reflect points of introduction early in the history of European settlement, from which the species can now only disperse very slowly.

*Salinator solida* is the most widely distributed saltmarsh gastropod, occurring throughout saltmarshes in all zones. Our collections extend Smith & Kershaw's (1981) records

TABLE 4
**Molluscs collected from Tasmanian saltmarshes**

Phylum MOLLUSCA
Class GASTROPODA
  Subclass PROSOBRANCHIA
  Order NOTAENIOGLOSSA
    Family LITTORINIDAE
      *Bembicium* sp.
  Order MONOTOCARDIA
    Family HYDROBIIDAE
      *Tatea rufilabris* (Adams, 1862)
    Family TRUNCATELLIDAE
      *Truncatella scalarina* Cox, 1867
    Family ASSIMINEIDAE
      *Assiminea buccinoides* (Quoy & Gaimard, 1835)
    Family HYDROCOCCIDAE
      *Hydrococcus brazieri* (Tennison-Woods, 1876)
  Order NEOGASTROPODA
    Family TEREBRIDAE

  Subclass PULMONATA
  Order BASOMMATOPHORA
    Family ELLOBIIDAE
      **Phytia myosotis* (Draparnaud, 1801)
      *Ophicardelus ornata* (Ferussac, 1821)
    Family AMPHIBOLIDAE
      *Salinator solida* (van Martens, 1878)
  Order SIGMURETHRA
  Family RHYTIDIDAE
      *Tasmaphena sinclairi* (Pfeiffer, 1845)
      *T. ruga* (Legrand, 1871)
      *Prolesophanta nelsonensis* (Brazier, 1871)
    Family ARIONIDAE
      **Arion intermedius* Normand, 1852
    Family SUCCINEIDAE
      *Succinea australis* (Ferussac, 1821)
Family LIMACIDAE
      **Deroceras reticulatum* (Muller, 1774)
      **Deroceras spp.*
    Family HELICIDAE
      **Cochlicella barbara* (Linnaeus, 1758)
      **Helix aspera* Muller, 1774
Class BIVALVIA
    Family MYTILIDAE
      *Xenostrobus securis* (Lamark, 1819)

* Introduced species.

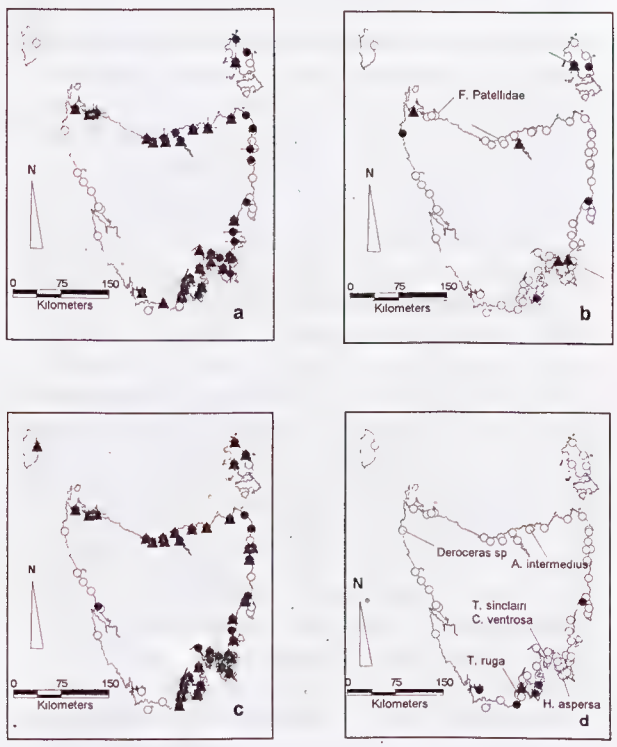


*FIG. 6A–D — Distribution of gastropods on Tasmanian saltmarshes. Collecting sites are marked by open circles. (A) Common prosobranchs. Closed circles* – Hydrococcus brazieri; *triangles* – Tatea rufilabris; *crosses* – Bembicium *sp. (B) Less-common prosobranchs. Closed circles* – Assiminea buccinoides; *triangles* – Truncatella scalarina; *dashes* – *F. Terebridae. (C) Amphibious pulmonates. Closed circles* – Salinator solida; *triangles* – Ophiocardelus ornata; *crosses* – Phytia myosotis; *large open circles* – Succinea australis. *(D) Terrestrial snails and slugs. Closed circles* – Prolesophanta nelsonensis; *triangles* – Deroceras reticulatum.

to cover the whole east coast. *S. solida* belongs to the family Amphibolidae, of which there are two species in Tasmania. This is the only pulmonate family with an operculum, an adaptation to life on land which allows the animal to seal its shell and so reduce water loss. This snail appears to be able to withstand extreme physical conditions, from submersion in saltwater to extended periods of desiccation, and so it can be considered to be well-adapted to life in the saltmarsh.

At the upper edges of saltmarshes and in backing vegetation, native forest snails (*Tasmaphena sinclairi, T. ruga* and *Prolesophanta nelsonensis*) were collected in small numbers (Figure 6D). In the same upper zone, the introduced slugs and helicid snails appeared, but none were numerous or widespread.

## DISCUSSION

The Tasmanian coastline provides a wide range of conditions of exposure and topography. The faunal diversity of the marshes reflects those areas where marshes have developed most extensively: in the indented, sheltered coast of the southeast and in the northwest, where sheltered shores and flat hinterland have allowed extensive saltmarshes to develop. Kirkpatrick & Glasby (1981) noted that several plant species were absent from the saltmarshes of the west and south coasts, and that others were confined to the southeast, east or northeast. A similar pattern appears in the crustacean and mollusc fauna, since several species are rare or absent on the west coast. Two factors which are likely to have contributed to this pattern are the cooler wetter climate in the west and the relatively poor development of saltmarsh there.

Apart from Marsh's (1982) localised study there have been no other faunal surveys of the Tasmanian saltmarsh fauna. Because of the lack of published work, it is difficult to put the diversity of the fauna of Tasmanian saltmarshes into a local context. It is likely that the general composition of the fauna of saltmarshes in mainland southeastern Australia is similar, since several gastropods recorded in Tasmanian marshes are also found there: *Tatea rufilabris, Ophicardelus ornata, Phytia myosotis* and *Salinator solida* (Smith & Kershaw 1981). The southeastern Australian marshes are also floristically similar (Kirkpatrick & Glasby 1981). Paviour-Smith (1956) recorded three species of talitrid amphipods, unidentified isopods and a grapsid crab but, apparently, no molluscs from a saltmarsh in the South Island of New Zealand, but it would be unwise to base any general conclusions about the faunal diversity of New Zealand saltmarshes on this single site.

Macnae (1957) described the saltmarsh fauna of the Zwartkops estuary which enters Algoa Bay just north of Port Elizabeth, South Africa. In the supralittoral fringe and the midlittoral, he recorded three talitrid amphipods (*Talorchestia australis, T. ancheidos* and *Parorchestia rectipalma*) and a melitid amphipod (*Melita zeylanica*), two isopods (*Tylos capensis* and a *Philoscia* sp.) and three species of crab (*Sesarma catenata, Cleistostoma edwardsi* and *Cyclograpsus punctatus*). The molluscan assemblage comprised the hydrobiid *Assiminea bifasciata* and a small unidentifed pulmonate at the supralittoral fringe, and *Littorina knysnaensis, Cerithidea decollata* and *Assiminea bifasciata* in beds of *Spartina stricta.*

North American saltmarsh faunas have been described in general terms by Daiber (1982). The molluscan fauna of marshes on the Atlantic seaboard typically includes the ribbed mussel *Geukensia demissa* and, in southern marshes, the marsh clam *Cyrenioda floridana.* The typical saltmarsh snails are the ellobiid *Melampus bidentatus* in the upper regions and the littorinid *Littoraria irrorata* lower on the marshes. The crustacean fauna is dominated by fiddler crabs, *Uca* spp., and other species, such as *Sesarma cinereum, S. reticulatum, Panopeus herbsti* and *Eurytium limosum.* The talitrid amphipod fauna includes *Uhlorchestia uhleri, Orchestia platensis, O. grillus* and *O. gammarella* (Bousfield 1973). The oniscoid isopod *Philoscia vittata* is abundant in New England saltmarshes (Dexter 1947).

The typical crustacean and molluscan assemblage of saltmarshes on the northeast coast of the Atlantic is described by Nichol (1936) and Healey (1975). The non-aquatic crustaceans consist of the beachflea *Orchestia gammarella,* woodlice, including *Porcellio scaber, Armidillidium vulgare, Philoscia muscorum* and (in Ireland) *Eluma purpurascens,* and a single crab, *Carcinus maenas.*The molluscs typically include ellobiids such as *Phytia* (= *Ovatella) myosotis,* the high-shore winkle *Littorina saxatilis* and smaller species such as *Phytia modesta.*

Very few studies have examined regional variation in the invertebrate faunas of saltmarshes elsewhere in the world. MacDonald (1969) surveyed the molluscan fauna of marshes and tidal creeks on the North American Pacific coast, recording over 70 species, but only five of these were consistently common on the marshes. He distinguished two zoogeographical regions at a scale extending over almost 25° of latitude, the Californian south of Point Conception and the Oregonian to the north. The study described here does not extend over such a large latitudinal scale, and the zoogeographic patterns which we have observed are explicable in terms of climatic differences between the west and east coasts, and the coastal topography, insofar as it affects the areal extent of individual marshes.

Our records of talitrid amphipods support the remarkable diversity of this group in Tasmania, already noted in other habitats (Friend 1987, Richardson *et al.* 1991, Richardson 1993, 1996). Only in New Zealand does a comparable diversity of species occur (Hurley 1957, Duncan 1994), but that fauna apparently lacks simplidactylate landhoppers. Two factors make saltmarshes the most probable habitat in which the evolution of the terrestrial habit in amphipods occurred: the very gradual transition from sea to land, and the presence of detritus from salt-adapted angiosperms in the intertidal zone (Richardson & Mulcahy 1996). Tasmania's diverse talitrid fauna, which includes examples of all the known phylogenetic and ecological groups, and the abundance of saltmarsh habitat provide a valuable opportunity to study the process of adaptation to land in one of only two crustacean groups to have made this major evolutionary transition successfully. This can be best done at sites where saltmarshes are backed by native vegetation that supports landhopper populations (i.e. wet forest), but such sites are becoming rare as the coastal zone is cleared (Richardson *et al.,* in press). A similar range of species with increasingly terrestrial adaptations is seen in the oniscoid isopods and the gastropods. In both groups, this study has revealed a range of species spanning the intertidal zone but, in these cases, several families are involved, compared to the single family of the Talitridae.

The common ellobiid snail of Tasmanian saltmarshes, *Ophiocardelus ornata,* appears to be the ecological equivalent of other saltmarsh ellobiids which have been well-studied

in other parts of the world. In North America, *Melampus bidentatus* is the dominant snail in saltmarshes of the east coast (Little 1990). *M. bidentatus* occupies the mid/upper areas of marshes which are covered by water 2–4% of the time. It can live submerged in water for several days, but it can also can tolerate the loss of up to 80% of its body water and then rehydrate rapidly afterwards. In Europe, the commonest saltmarsh pulmonate is the ellobiid *Phytia* (=*Ovatella) myosotis,* which shows many physiological parallels with *Melampus,* including the ability to withstand a change in the salt concentration from freshwater to a salinity of nearly three times seawater (Little 1990). Eco-physiological studies on *O. ornata* may reveal similar adaptations; however, virtually nothing is known of this species.

Ellobiid snails are true saltmarsh species, one of the few groups of animals inhabiting their mid regions and, hence, are of particular interest, because their characteristics represent a state similar to that in the primitive ancestors of the true land snails, the Stylommatophora. Saltmarsh ellobiids are the most primitive of their family. They have successfully adapted to the harsh "barrier zone" at the top of the saltmarsh, and Little (1990) believes that little more than behavioural changes would be needed to adapt them to a terrestrial existence; indeed, some of the Ellobiidae have already become terrestrial. The existence of these snails in saltmarshes suggests that, as for the landhoppers, this may be one of the pathways along which snails have evolved from sea to land (Little 1990).

This study has shown that the crustacean and mollusc fauna of Tasmanian saltmarshes is diverse and interesting, and the habitat provides many opportunities for further ecological and physiological studies.

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# ASPECTS OF THE DISTRIBUTION, PHYTOSOCIOLOGY, ECOLOGY AND MANAGEMENT OF *DANTHONIA POPINENSIS* D.I. MORRIS, AN ENDANGERED WALLABY GRASS FROM TASMANIA

by Louise Gilfedder and J.B. Kirkpatrick

(with four tables and two text-figures)

GILFEDDER, LOUISE & KIRKPATRICK, J. B., 1997 (31:viii): Aspects of the distribution, phytosociology, ecology and management of *Danthonia popinensis* D.I. Morris, an endangered wallaby grass from Tasmania. ISSN 0080-4703. *Pap. Proc. R. Soc. Tasm.* 131: 31–35. Parks and Wildlife Service, GPO Box 44A Hobart, Tasmania, Australia 7001, formerly Department of Geography and Environmental Studies (LG); Department of Geography and Environmental Studies, University of Tasmania, GPO Box 252-78, Hobart, Tasmania, Australia 7001 (JBK).

*Danthonia popinensis* is a recently discovered, nationally endangered tussock grass, originally known from only one roadside population at Kempton, Tasmania. Six populations have been recorded, all from flat land with mildly acid non-rocky soils, and all in small roadside or paddock remnants, badly invaded by exotic plants. However, one site has recently been destroyed through roadworks. The species germinates best at temperatures of 10°C, indicating a winter germination strategy. Autumn burning at Kempton resulted in an increased cover of *D. popinensis* two years after the burn, but also resulted in an increased cover of competitive exotics. The future of the species needs to be secured by *ex situ* plantings, as almost all of its original habitat has been converted to crops or improved pasture.
**Key Words: Danthonia popinensis, wallaby grass, tussock grass, endangered species, Tasmania.**

## INTRODUCTION

*Danthonia popinensis* was first collected in 1985 from a grassy roadside verge at Kempton, in southern Tasmania, and was subsequently described (Morris 1990) and listed as nationally endangered (Briggs & Leigh 1988, Leigh & Briggs 1992). It is a tall grass up to 0.45 m high, distinguished by abundant hairs scattered between the upper and lower rows of hair tufts on the lemma and the broad, flat blades of the lower leaves. Much of the native vegetation in the region has been modified or lost through agricultural or urban development (Gilfedder & Kirkpatrick 1995).

The Kempton site consists of a roadside which has suffered major soil disturbance during roadworks and is heavily invaded by exotic species, including suckers from a historic planting of elms (*Ulmus* X *hollandica*) in the adjacent sheep paddock on private land.

The site had been subject to roadside management normal in the area, in that it was regularly slashed to reduce the above-ground biomass. When the species was first discovered, there was concern that the practice of slashing might lead to the loss of *D. popinensis* individuals, through accidental deep mechanical scraping or the encouragement of competition from exotic plants. Cuttings were left *in situ* following slashing. This practice may favour the germination and establishment of exotic species over native species, many of which prefer bare intertussock spaces (Kirkpatrick 1986, Stuwe 1986). As a consequence of these concerns, slashing ceased on the section of the roadside with *D. popinensis* in 1989. However, *Ulmus* suckers and exotic grasses soon began to proliferate. At this point, it was decided that it was worth determining whether burning would favour *D. popinensis* and set back the exotic species.

Fire plays an important ecological role in temperate Australian lowland grassy ecosystems (e.g. Robertson 1985, Stuwe & Parsons 1987, McDougall 1989, Lunt 1995). In general, late summer or autumn burning has been the most common fire management regime (e.g. McDougall 1989); this timing is particularly important for the regeneration of native legumes (Scarlett & Parsons 1982), although Lunt (1990) cautions that burning in this season favours many exotic species.

This paper reports the effects of an autumn burn on *D. popinensis* and associated native and exotic species at Kempton. It also documents the distribution, environment and phytosociological context of this endangered species, presents some data on its germination requirements and suggests means to ensure its future.

## METHODS

### Floristic Patterns

The distribution of *D. popinensis* was determined from herbarium collections, literature references and field survey data. At each site where *D. popinensis* occurred, floristic data were collected from a quadrat measuring 1 x 10 m. Data were stored on DECODA (Minchin 1990). The polythetic divisive technique TWINSPAN (two-way indicator species analysis – Hill 1979) was used to obtain a sorting of samples. A dissimilarity matrix was calculated with this binary data, using the Czekanowski (Bray-Curtis) coefficient, and was used to help produce a sorted table. Environmental data were also obtained. Altitude, surface geology and soil type were noted in the field, and the slope and aspect of each site were determined using a clinometer and compass respectively. Climatic data were derived for each site, using the Bioclimatic Prediction System (Busby 1988), which produces 16 parameters characterising annual, seasonal and extreme components of the climatic environment. Species nomenclature follows Buchanan (1995).

## Experimental Burn

The impact of an autumn burn was studied. Transects were placed parallel with the roadway and through the densest areas of *D. popinensis* at Kempton. Forty-five 0.4 x 0.4 m quadrats were placed at 1 m intervals along the transect line. Data were obtained on the number of *D. popinensis* individuals and the number of clumps or tussocks that these individuals cumulatively comprised, the number of flowers and the number of germinants, and the number of *Ulmus* suckers and individuals per quadrat. The distributions and covers of individual species and types of ground cover (litter, bare) were mapped. After mapping, half the site was burned on 20 May 1991. Twenty quadrats were in the burned plots and 25 quadrats were in the unburned vegetation. The vegetation in the quadrats was remeasured on 25 November 1993. Mann-Whitney *U* Tests (Siegel 1956) on the program MINITAB (Release 6.2, Macintosh® version) were used to determine if the densities of *D. popinensis* and *Ulmus* suckers, and the nature of the ground cover, were significantly different pre-fire from those in 1993 for both burned and unburned quadrats. Owing to the small size of the population, the experiment was pseudoreplicated, with the two sets of quadrats not being identical at their starting point. Therefore, differences in the rates of change within each treatment were looked for since, if the burned area had significant differences in values between 1991 and 1993 and the unburned area did not, burning was responsible for the direction of the significant change. Due to low numbers for some taxa, data were pooled into lifeform categories (i.e. annual exotic grasses, exotic perennial grasses and native perennial grasses) for analysis.

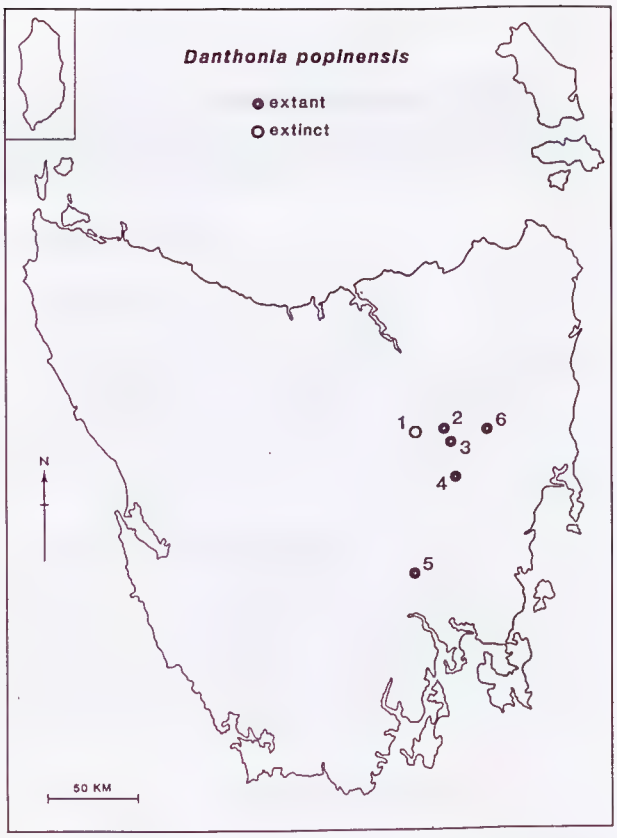


*FIG. 1. — Distribution of* Danthonia popinensis.
*1 = Valleyfield Rd, via Campbell Town, 2 = Conara/Nile Rd, 3 = Conara/Midland Hwy, 4 = Ross, 5 = Kempton, 6 = Avoca.*

## Germination Trials

Seeds were collected from 30 individual plants of *D. popinensis* from the Kempton population on 18 February 1991. Germination tests were carried out by placing the seed on moist double layers of filter paper (Whatman No. 1) in 90 mm Petri dishes on 16 June 1991. For each trial there were five replicates of 20 seeds placed in randomised blocks. The seeds were checked twice daily and watered with distilled water when necessary, ensuring that the filter paper was maintained in a moist but not wet condition. The seed was germinated in an incubator in dark conditions, with the seeds being exposed to light when watered. Four temperatures were used: 5°, 10°, 15° and 20°C, with no pretreatment.

# RESULTS

## Floristic Patterns

In the decade following the discovery of *D. popinensis,* an additional five collections of the species were made (fig. 1), all in small native vegetation remnants in the Midlands. All sites are on flat or extremely gently sloping ground, on rock-free soils. The underlying geology varies from sand sheets to dolerite (table 1). The topsoils are sandy loam or sandy clay loam, with a pH in the range 6.0 to 6.5. Mean annual precipitation varies from 555 to 625 mm, with the driest quarter receiving 115–119 mm (table 2). The mean temperature of the warmest month varies from 14.5–16.1°C, while the mean temperature of the coolest month varies from 6.1–6.5°C (table 2).

The majority of records are of small populations in weed-infested vegetation on roadside verges (tables 1, 3). One roadside site has been destroyed through roadworks and road maintenance activities. At one site the species occurred as a rare component of *Eucalyptus amygdalina* grassy woodland, which has been ungrazed for more than 20 years. Another site is partly wetland, with species such as *Lythrum hyssopifolia* and *Eleocharis acuta* (table 3). The percentage of exotic species per site varied from 24% to 71%. The quadrats were highly dissimilar in their species composition, with eight out of 15 Bray-Curtis dissimilarity values exceeding 0.8 and the remainder exceeding 0.7.

## Experimental Burn

The burn encouraged the resprouting of *Ulmus* rather than killing the suckers. Whilst the number of *Ulmus* individuals did not vary significantly between the burned and unburned site and between 1991 and 1993, there was a marked increase in the percentage cover of suckers in the burned plots (table 4). A similar trend was found for *D. popinensis* — the use of fire did not significantly influence the number of individuals or tussocks, but the percentage cover significantly increased in the burned plots (table 4). Only nine new germinates of *D. popinensis* were recorded as establishing in plots between 1991 and 1993, seven in the

TABLE 1
Features of sites with *Danthonia popinensis*

| Quadrat number | Locality | Native species richness | Altitude | Geology | Tenure |
|---|---|---|---|---|---|
| 1 | Valleyfield Road | 14 | 160 | sandstone | roadside |
| 2 | Conara/Nile Road | 18 | 200 | wind-blown sand | private |
| 3 | Conara/Midland Hwy | 13 | 180 | dolerite | roadside |
| 4 | Ross | 5 | 180 | dolerite | roadside |
| 5 | Kempton | 7 | 190 | sandstone | roadside |
| 6 | Avoca | 10 | 180 | sands and gravels | roadside |

TABLE 2
Climatic data for sites at which *Danthonia popinensis* occurs*

| Climatic variable | Values† | |
|---|---|---|
| | Mean | Range |
| annual mean temperature (°C) | 10.96 | 10.1-11.3 |
| minimum mean temperature of the coolest month (°C) | 1.40 | 1.1-1.8 |
| maximum mean temperature of the warmest month (°C) | 22.96 | 21.3-23.6 |
| annual temperature range (°C) | 21.48 | 19.3-22.6 |
| mean temperature of the coolest quarter (°C) | 6.42 | 6.1-6.5 |
| mean temperature of the warmest quarter (°C) | 15.64 | 14.5-16.1 |
| mean temperature of the wettest quarter (°C) | 8.30 | 7.3-11 |
| mean temperature of the driest quarter (°C) | 15.92 | 15.5-16.1 |
| coefficient of variation of monthly precipitation (°C) | 15.20 | 12.5-17.8 |
| mean annual rainfall (mm) | 591.25 | 555-625 |
| rainfall of the wettest quarter (mm) | 171.50 | 156-188 |
| rainfall of the driest quarter (mm) | 117.00 | 115-119 |
| rainfall of the coolest quarter (mm) | 165.25 | 143-183 |
| rainfall of the warmest quarter (°C) | 117.25 | 115-120 |

* Derived from Bioclim (Busby 1988).
† Mean values and range are from the six sites at which the species has been recorded.

burned plots. The flowering rate of *D. popinensis* decreased following fire (table 4).

The burn had a dramatic impact on the nature of the ground cover at the Kempton site. The percentage cover of annual grasses, such as *Briza minor, Vulpia myuros, Aira caryophyllea* and *Bromus hordeaceus,* increased significantly post-fire, up to a mean percentage cover of 46.2%, but remained at low levels in the unburned plots (table 4). Exotic perennial grass cover decreased in the burned plots (table 4), and the fire had no significant impact on the percentage cover of native perennial grasses (*Stipa, Danthonia*)(table 3). Bare ground was less at the end of the measurement period in the burned area than in the unburned area. Herb cover increased in both burned and unburned plots between 1991 and 1993 (table 4).

### Germination Trials

*D. popinensis* failed to germinate at 5°C, with poor germination (<10% of seeds) at 20°C. Germination was moderate (<35%) at 15°C and best at 10°C with >70% of seed germinating (fig. 2).

## DISCUSSION

The fact that the few known populations of *D. popinensis* are on non-rocky soils on gentle slopes on a range of soil types and geologies suggests that the species may have been more common before the agricultural and pastoral invasion, as most of the native vegetation on these types of sites in subhumid Tasmania has been destroyed or severely degraded (Gilfedder & Kirkpatrick 1995), including one of the recently discovered sites of *D. popinensis.*

The successful germination of *D. popinensis* at 10°C indicates that it is a species that may be adapted to germinate in winter, the coolest and the moistest season, and it has a relatively high fecundity at this temperature. The mean temperature of the wettest quarter for sites where *D. popinensis* occurs is 8.3°C and the annual mean temperature is 10.96°C, indicating climatic conditions favourable for germination. It is assumed that *D. popinensis* is capable of vegetative spread, as indicated by the increase in tussock size and an increase in the percentage cover between 1991 and 1993. The degree to which intertussock gaps are necessary to ensure replenishment of the population is uncertain, given that the species has survived, albeit in low

TABLE 3
**Sorted table for quadrats with *Danthonia popinensis***

| Species* | Site† 234516 |
|---|---|
| *Acaena agnipila* | 11---- |
| **Trifolium repens* | 1-1--- |
| **Acetosella vulgaris* | 111--1 |
| **Trifolium subterraneum* | 1--1-- |
| **T. dubium* | 1--1-- |
| *Acaena echinata* | 11-1-- |
| **Cirsium vulgare* | -11--- |
| *Poa labillardierei* | -11--- |
| **Tragopogon porrifolius* | -11--- |
| **Dactylis glomerata* | -111-- |
| **Avena fatua* | -1-1-- |
| *Cynoglossum suaveolens* | -1-1-- |
| **Bromus mollis* | -1-1-- |
| **Aira caryophyllea* | -1-1-- |
| *Pentapogon quadrifidus* | -1-1-- |
| *Carex breviculmis* | --11-- |
| **Plantago coronopus* | --11-- |
| *Acacia dealbata* | 1----1 |
| *Danthonia popinensis* | 111111 |
| *Themeda triandra* | 11--11 |
| **Agrostis capillaris* | --111- |
| *Danthonia caespitosa* | 1--11- |
| *D. laevis* | 1--1 1- |
| **Cynosorus echinatus* | ---1 1- |
| **Bromus diandrus* | ---1-1 |
| *Pimelea humilis* | ---1-1 |
| *Ehrharta stipoides* | 1---11 |
| **Hypochoeris radicata* | -1--11 |
| *Lomandra longifolia* | --1-11 |

Additional Species

2: **Arctotheca calendula, Banksia marginata, *Cerastium glomeratum, Gnaphalium collinum, *Holcus lanatus, Hypericum gramineum, Hypoxis glabella, Lagenifera stipitata, Leptorhynchos squamatus, Lissanthe strigosa, Oxalis perennans, Thelymitra* spp., *Wahlenbergia gymnoclada.*

3: **Centaurium erythraea, Chrysocephalum apiculatum, Convolvulus erubescens, Danthonia carphoides, *Petrorhagia prolifera, *Plantago lanceolata, *Poa bulbosa, Rumex dumosus, *Sonchus oleraceus, Stipa flavescens, *Trifolium pratense, Vittadinia gracilis.*

4: **Erodium cicutarium, *Medicago* spp., *Rumex crispus.*

5: **Lolium perenne, *Moenchia erecta, *Poa pratensis, *Silene gallica, *Trifolium glomeratum, *Ulmus X hollandica, *Vulpia myuros.*

1: **Agrostis stolonifera, Amphibromus nervosus, *Anthoxanthum odoratum, *Cyperus tenellus, Dichondra repens, Eleocharis acuta, Eleocharis pusilla, Eryngium vesiculosum, Isolepis crassiuscula, Isolepis platycarpa, Juncus bufonius, Juncus holoschoenus, *Leontodon taraxacoides, Lythrum hyssopifolia.*

6: *Acrotriche serrulata, *Briza* spp., *Dianella revoluta, *Erodium botrys, *Genista monspessulana, Hibbertia prostrata, Lepidosperma gunnii, *Pinus radiata, Pultenaea pedunculata, *Vulpia bromoides*

* = Introduced species.

† 1 = Valleyfield Rd, via Campbell Town, 2 = Conara/Nile Rd, 3 = Conara/Midland Hwy, 4 = Ross, 5 = Kempton, 6 = Avoca.

TABLE 4
**Mean and standard error of the number of *Danthonia popinensis*†, *Ulmus*‡, and the cover of bare ground§ per 0.16 m² in burned and unburned quadrats.**

| | 1991 | 1993 | Significance levels¶ |
|---|---|---|---|
| *D. popinensis* tussocks | | | |
| burned | 6.70 ± 1.05 | 6.30 ± 1.12 | n.s. |
| unburned | 4.76 ± 1.40 | 4.56 ± 1.30 | n.s. |
| *D. popinensis* individuals | | | |
| burned | 33.95 ± 5.35 | 37.00 ± 7.26 | n.s. |
| unburned | 28.56 ± 6.26 | 31.44 ± 6.63 | n.s. |
| *D. popinensis* percentage cover | | | |
| burned | 4.20 ± 0.186 | 5.60 ± 0.169 | *** |
| unburned | 3.60 ± 0.294 | 3.76 ± 0.284 | n.s. |
| *D. popinensis* flowers | | | |
| burned | 3.80 ± 0.213 | 1.65 ± 0.196 | *** |
| unburned | 4.28 ± 0.334 | 3.96 ± 0.329 | n.s. |
| *Ulmus* suckers | | | |
| burned | 1.10 ± 0.240 | 1.45 ± 0.328 | n.s. |
| unburned | 0.40 ± 0.129 | 0.40 ± 0.129 | n.s. |
| *Ulmus* percentage cover | | | |
| burned | 1.17 ± 0.459 | 4.75 ± 1.42 | * |
| unburned | 0.36 ± 0.114 | 0.36 ± 0.114 | n.s. |
| bare ground percentage cover | | | |
| burned | 29.65 ± 4.72 | 3.05 ± 0.803 | *** |
| unburned | 49.04 ± 4.96 | 48.52 ± 4.71 | n.s. |
| annual grasses percentage cover | | | |
| burned | 13.45 ± 2.63 | 46.20 ± 6.27 | *** |
| unburned | 14.39 ± 2.88 | 22.96 ± 4.17 | n.s. |
| exotic perennial grasses percentage cover | | | |
| burned | 24.55 ± 4.20 | 7.50 ± 2.19 | *** |
| unburned | 20.39 ± 9.84 | 22.70 ± 10.3 | n.s. |
| native perennial grasses percentage cover | | | |
| burned | 17.00 ± 2.44 | 18.00 ± 3.05 | n.s. |
| unburned | 8.17 ± 1.22 | 9.48 ± 1.38 | n.s. |
| perennial grasses percentage cover | | | |
| burned | 41.55 ± 4.46 | 25.50 ± 3.02 | * |
| unburned | 28.57 ± 9.52 | 32.13 ± 9.84 | n.s. |
| grass cover (Braun-Blanquet) | | | |
| burned | 4.20 ± 0.186 | 5.60 ± 0.169 | *** |
| unburned | 3.60 ± 0.294 | 3.76 ± 0.284 | n.s. |
| herb cover (Braun-Blanquet) | | | |
| burned | 2.30 ± 0.282 | 1.10 ± 0.069 | *** |
| unburned | 1.12 ± 0.105 | 2.00 ± 0.163 | *** |
| exotic cover (Braun-Blanquet) | | | |
| burned | 3.65 ± 0.209 | 4.90 ± 0.228 | *** |
| unburned | 1.92 ± 0.264 | 2.24 ± 0.290 | n.s. |

† Individuals, tussocks, cover and flowers

‡ Suckers and covers.

§ Grass, herb, exotic species, annual grasses, perennial exotic grasses, native perennial grasses and perennial grasses.

¶ For the Mann-Whitney U Test: * = P<0.05, ** = P<0.01, *** = P<0.001, n.s. = not significant.

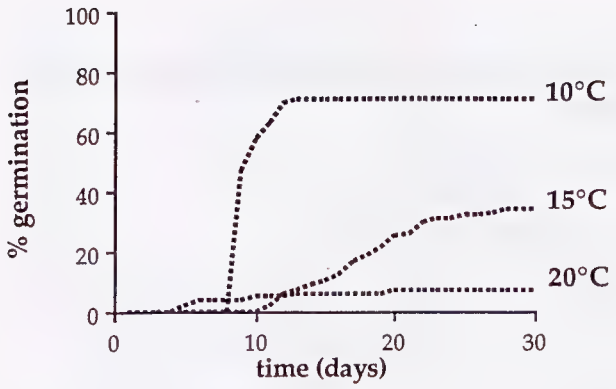


*FIG. 2. — Germination curves for* Danthonia popinensis

density, in a remnant undisturbed for 20 years. Also, the rate of establishment of new individuals at Kempton in the period 1991–93 was low, despite bare ground being available, particularly in the unburned plots, where exotic annual grasses were not favoured. Seven of the nine germinates of *D. popinensis* established in bare ground. Nevertheless, the rate of establishment is probably sufficient to maintain the population.

Autumn burning was not an effective strategy for weed control in the Kempton population. Although the biomass of *D. popinensis* increased significantly with burning, so too did the area of *Ulmus* suckers. Autumn burning at Kempton also favoured the germination of exotic annual grasses, particularly *Vulpia myuros,* in the bare ground characterising intertussock gaps. This has also been recorded in *Themeda triandra* grasslands in Victoria, where annual grasses were promoted by burning, and *V. bromioides* increased 100-fold, following an autumn fire (Lunt 1990).

At Kempton, the control of *Ulmus* suckers has recently been achieved in the short term by a return to the previous management of slashing. For roadside sites as a whole, the effects of spring burning should also be investigated. The selective use of herbicide is another option that deserves investigation for weed control, as an accidental spraying of the site in autumn with Roundup® did not appear to negatively affect *D. popinensis.*

The long-term security of *D. popinensis* in the wild is poor, as all the sites are small fragments of the original vegetation. The creation of an *ex situ* population at a secure and ecologically suitable site is recommended, as is the use of the species in roadside amenity plantings within its present range.

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# THE VEGETATION AND FLORA OF THREE HUMMOCK ISLAND, WESTERN BASS STRAIT

by Stephen Harris and Jayne Balmer

(with one table, four text-figures, nine plates and an appendix)

HARRIS, S. & BALMER, J., 1997 (31:viii): The vegetation and flora of Three Hummock Island, western Bass Strait. *Pap. Proc. R. Soc. Tasm.* 131: 37–56. ISSN 0800-4703. Parks and Wildlife Service, Department of Environment and Land Management, GPO Box 44A, Hobart, Tasmania, Australia 7001.

A survey of the vegetation of Three Hummock Island Nature Reserve recorded 289 vascular higher plant species, 60 of which were introduced. Of the native flora, six are classified as rare or vulnerable. Clarke Island, at a similar latitude in Eastern Bass Strait, has a significantly richer flora, including an element of Mainland Australian/Bassian flora for which the island is the southernmost limit. In contrast, there are no species known from Three Hummock Island that do not occur on mainland Tasmania. The greater length of time during which the land bridge at the eastern end of Bass Strait was exposed is, therefore, reflected in the flora. Three Hummock Island was cut off for a much longer period with no land connections to the north, therefore has a more insular Tasmanian flora. Climatic differences may have exacerbated the contrast.

Nine vegetation mapping communities are defined, the largest proportion of the island being covered by Myrtaceae-dominated scrub. The main changes in the vegetation since the time of European discovery have been the clearing of much of the relatively fertile calcareous sands for grazing and the consequent loss of most of the *Eucalyptus viminalis* forests, an increased fire frequency and the introduction of exotic plants. Fire and weeds are the major vegetation management issues on the island.

**Key Words: Flora, vegetation, Bass Strait, Tasmania, biogeography, Three Hummock Island, Nature Reserve, Clarke Island, coastal vegetation**

## INTRODUCTION

Three Hummock Island comprises 7284 ha and is one of the three larger islands in the Hunter Group off northwestern Tasmania (fig. 1). Despite this, there is a surprising dearth of published information about the vegetation. What little there is, either is very general and results from broad extrapolation with little or no fieldwork on the island, or treats specific aspects of the flora within a more general state context.

Some vegetation types have been examined in broader systematic studies. Kirkpatrick (1977) sampled the heathland vegetation and Kirkpatrick & Harris (1995) reported the results of an analysis of coastal plant communities which included samples from Three Hummock Island. Kirkpatrick & Harwood (1981, 1983a, b) sampled four lagoons on the island in their statewide wetland survey. Oblique or casual references to the vegetation or flora of the island have been made by Atkinson (1890), Alliston (1966) and some early navigators, including Baudin (Cornell 1974) and Bass (Collins 1802). The island vegetation has been mapped at 1:500 000 from air photo interpretation (Kirkpatrick & Dickinson 1984), and land systems, i.e. soil/geomorphic/vegetation units, were mapped by Richley (1984). The island is known to have been prospected for orchids, and parties of natural history enthusiasts have visited the island from time to time.

The island has been Crown land, held under lease since at least before 1850 but resumed by the Crown in 1976, and subsequently proclaimed a Nature Reserve under the *National Parks and Wildlife Act* 1970 by virtue of Statutory Rule No. 303 of 1977. Fire management has since become one of the most important issues for the Parks and Wildlife Service. Fire management planning requires information about the vegetation. This was one of the primary motives for the present study. The inventory of species and plant communities in a Nature Reserve also assists nature conservation planning in a state context. Biological surveys of islands have been recommended as a national priority (McNamara 1989).

The aims of this study were to prepare a detailed vegetation map, describe the plant communities on the island and the major factors influencing vegetation pattern, and record the higher plants observed on the island.

## METHODS

Two weeks were spent on the island between 2 and 14 October 1995. During this time the island was traversed on foot, in order to sample the full range of vegetation types likely to be found on the island as well as all likely plant species habitats. Fifty-nine 100 $m^2$ plots were located subjectively, without preconceived bias (Mueller-Dombois & Ellenberg 1974) in the range of vegetation types, and used for descriptions of structure, species composition and, if possible, age since last fire. A species list was compiled on transects through similar vegetation types and locations of plot and point-based observations were marked directly on an aerial photograph enlargement. Specimens of most higher plant species observed were collected and the material was subsequently lodged in the Tasmanian Herbarium.

Apparent vegetation types were delineated on 1993, 1:50 000 black and white aerial photographs and checked in the field. Structural nomenclature follows Specht (1970) and plant nomenclature follows Buchanan (1995). Grid references given in the text are standard AMG grid references from the Tasmap 1:100 000 map sheet 7816 *Hunter*.

Human disturbances can have a major impact on island species equilibrium (Whittaker 1995). Historical sources were examined to help determine vegetation change on Three Hummock Island.

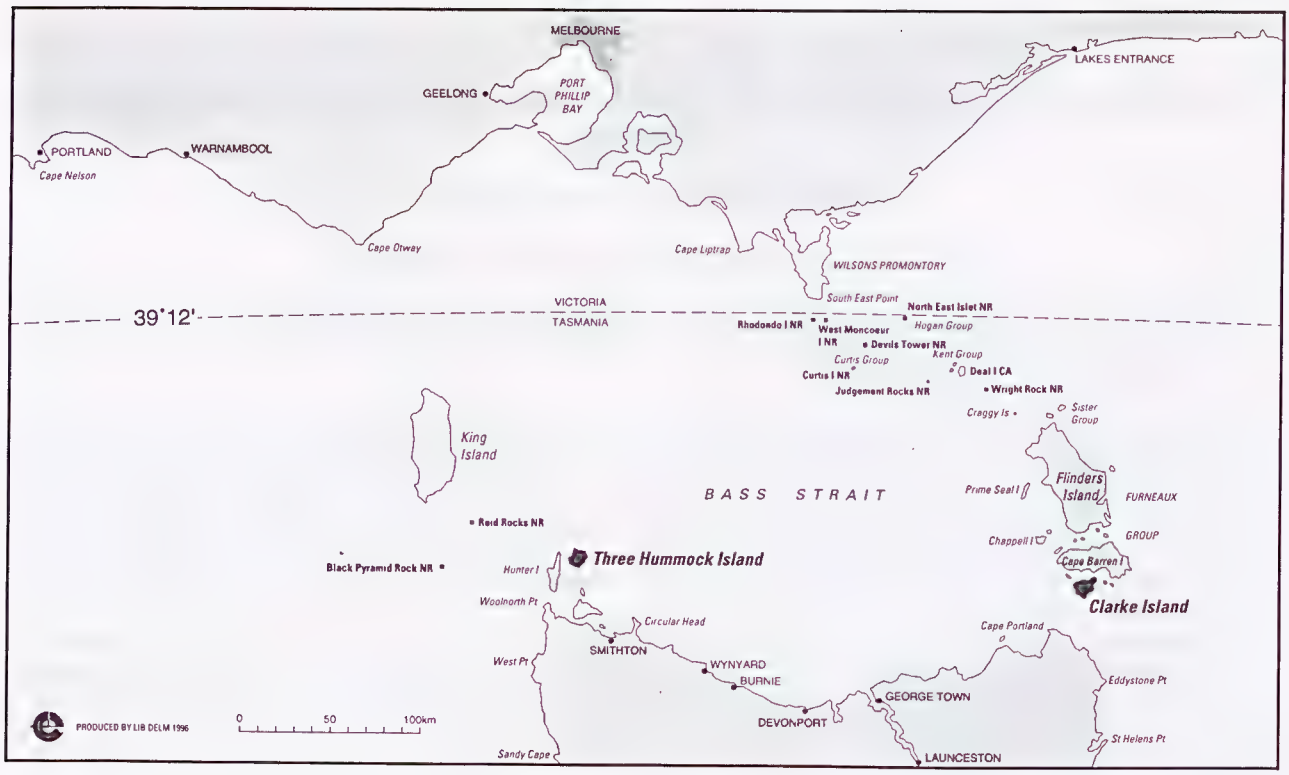


*FIG. 1 — Location of the study area and Clarke Island.*

## A BRIEF HISTORY OF THE ISLAND.

There are very few early historical references to the islands in the Hunter Group. The islands were not known to Europeans at all until Bass' voyage from the east in 1798 through the strait bearing his name. Three Hummock Island was named by Flinders who anchored on the north coast of the island in 1798. The wreck of the *Sydney Cove* (1797) in the Furneaux Group led almost directly to the discovery of the Strait, which soon after became the route for shipping from Europe rather than around the "Cape of Van Diemen". Interest in western Bass Strait by the early navigators around the turn of the 18th century was probably due in part to the new strategic importance to shipping of the western approaches to the Strait.

The earliest reference, albeit indirect, to the vegetation of Three Hummock Island was given by Bass in his journal of his exploratory voyage of 1798 and reported in Collins (1802):

> "There was reason to believe, that the sea here had a communication through into the unexplored bight to the eastward of Three Hummock Island; in which case the pointed part of the main, whose vegetation bore so great a resemblance to that of Three Hummock Island, would also be an island."

Earlier, Collins further gave the description from Bass of the vegetation of Hunter Island: "... pointed part of the main, which in height and starved vegetation very much resembled Three Hummock Island."

Bowdler (1980) cited an account by Flinders of Bass's landfall on Three Hummock Island where Flinders stated that Bass "....found it impenetrable from the closeness of the tall brush wood, although it had been partially burnt not long before".

Only a few years later, Freycinet (reproduced in Plomley 1983) of the 1802 Baudin expedition described his landing on Three Hummock Island:

> "We landed only once, towards the western end of Coulomb Bay. Our landing was accomplished easily in a little sandy cove, well sheltered and very snug, whose heads were low and composed of a grey micaceous granite. This part of the island is wooded yet lacking tall trees. A little distance from the shore the terrain is extremely sandy, but on moving further into the interior one finds land of quite good quality covered with several different kinds of plants. We perambulated the woods in different directions. They are so tangled and so obstructed with trees blown down by the winds that we had difficulty getting out of them. We often saw large masses of granite sticking out of the ground."

It appears then that the island had dense scrubby vegetation. If the island had been free of fire for millennia, then tall forests with much more open understorey would be expected. Pre-European sources of fire would have been lightning and Aboriginal visitors. Plomley stated (1983: 193) that there was evidence of Aboriginal use of the island and suggested that Baudin's expedition might have noted the Aboriginal smokes because "... one of the reference points was designated *pointe de la fumée* ('smoky point' = Point Cassard)".

Subsequent references to the island in the 19th century are sparse. It seems that the island had settlers prior to 1852. The Italian revolutionary, Garibaldi, who visited the island in 1852, stated (Garibaldi 1889, quoted in AOT corres. file):

> "1852. In the Indian Ocean, outside the Straits of Lombok, we found the breezes constant from the east,

at a few degrees distance. Keeping the ship's head to the wind, we continued as far as about 40°S., when, finding the wind westerly, we passed through Bass's Strait, between Australia and Van Diemen's Land. Touching at one of the Hunter Islands, to take in water, we found a small farm, lately deserted by an Englishman and his wife, on the death of his partner. This information was obtained from a board erected on the settler's grave, which set forth in brief the history of the little colony. 'The husband and wife', said the inscription, 'unable to bear the lonliness [sic] of the desert island, left it, and returned to Van Diemen.'

"The most important part of the settlement was a little one-storied dwelling-house, rough, but comfortable, carefully built, and furnished with tables, beds, and chairs — not luxurious, indeed, but all bearing the impress of that comfort which seems so natural to the English. We also found a garden — a most useful discovery, as it enabled us to take on board an abundant supply of fresh potatoes and other vegetables.

"How often has that lonely island in Bass's Strait deliciously excited my imagination, when, sick of this civilized society so well supplied with priests and police agents, I returned in thought to that pleasant bay, where my first landing startled a fine covey of partridges, and where, amid lofty trees of a century's growth, murmered [sic] the clearest, the most poetical of brooks, where we quenched our thirst with delight, and found an abundant supply of water for the voyage."

It is likely that Garibaldi anchored at Chimney Corner (R. Alliston, pers. comm.). There is no tall forest near this vicinity today.

Atkinson (1890) reported on a visit to the island in November that year. By this time the island was being leased from the government by Captain John Burgess. Burgess had cleared some areas of the island. Atkinson described his attempts to attain the summit of South Hummock, which, at the first instance, was prevented by the dense scrub. The second successful attempt was also a struggle, "walking, cutting and crawling through one of the densest scrubs I ever experienced ..." Interestingly, the only plants Atkinson mentions are ones collected near the summit and with which he is not familiar, but which occur widely over the island. These were determined for him by Baron von Mueller and are *Styphelia lanceolata* (most likely *Leucopogon australis*), *Pimelea ligustrina* (could this have been *P. linifolia*, which is common?), *Phyllanthus gunnii* and *Boronia polygalifolia* (= *B. anemonifolia*). Atkinson remarks that these are "all rather rare". Except for *P. gunnii*, which is sparsely distributed, these determinations probably represent species which are now extremely common on the island.

Since at least the mid 1800s, the island has been a farm, and some of the sandy areas were eventually cleared for stock grazing. Many of these areas are now reverting to scrub, but for many years there was regular burning of sandy areas each spring to keep back the scrub and encourage the grasses. Sowing of exotic grass species was carried out, with regular top-dressing with superphosphate and trace elements (Co, Cu) on the more acid soils (J. Alliston pers. comm.). Some cultivation occurred on the better home paddocks, and the only known patch of basaltic soil on the island, behind East Telegraph Beach, was cleared, ploughed and sown to potatoes (Alliston 1966).

Since the lease on the island was resumed by the Government in 1976, the former lessees retain a life tenancy of the homestead at Chimney Corner. The island is now managed as a Nature Reserve. So far, this has involved maintaining a flock of sheep on the home paddocks, which helps to preserve an effective fire break for the buildings at Chimney Corner and keep the home airstrip open. Some firing has been carried out, with the aim of protecting built assets. Marram grass (*Ammophila arenaria*) planting was carried out by the Parks and Wildlife Service on the large sand blowout behind West Telegraph Beach in 1986, but trial planting of Marram grass was carried out on the island in the 1940s. Commercial activity carried out on the island is seasonal muttonbirding in March and April. The island is also used as an interchange by abalone poachers, who fly out illegally harvested shellfish from the Telecom airstrip in the centre of the island. The airstrip was constructed in 1973 for servicing a now-defunct telecommunications tower on South Hummock. An area of 58.2 $m^2$ near Cape Rochon is owned by the Commonwealth Government for lighthouse purposes.

## PHYSICAL DESCRIPTION AND CLIMATE

### Location and Climate

Three Hummock Island is situated 30 km north of the northwest corner of the Tasmanian mainland and 4 km east of the northern end of Hunter Island. It is at latitude 40° 25' longitude 144° 55' and so experiences the full impact of the "Roaring Forties" with the consequent strong westerly prevailing wind. The average rainfall is 939 mm per annum. The minimum recorded annual rainfall is 651 mm and the maximum recorded annual rainfall is 1233 mm (Bureau of Meteorology 1996). Rain falls throughout the year, with a maximum of 228 mm in July and a minimum of 10 mm in February (Bureau of Meteorology 1996). The temperature is mild throughout the year, with a daily average minimum of about 13°C and a daily average maximum of about 20°C for February. The daily average minimum in July is 8°C and the daily average maximum in the same month is 12.9°C (Bureau of Meteorology 1996).

### Geology and Soils

Three Hummock Island is compact in shape and has about 50 km of coastline, of which about 40 km consist of exposed granite outcrops, while 10 km consist of sandy beaches and dunes.

The geology of Three Hummock Island has been described by Jennings (1976) as "simple, consisting of a single granite pluton, with only small rare inclusions of original host sediments". The granite (Lower Carboniferous–Devonian) is not otherwise known from the northwestern island region of Tasmania. Elsewhere in this region (but absent from Three Hummock), Precambrian sediments predominate (Richley 1984, Jennings & Cox 1978). There is a small area of basalt (0.3 $km^2$) about 1 km from East Telegraph beach.

Three contrasting soils are recorded for the island. The soil which overlies the basalt is a brown sandy loam (Jennings 1976). Overlying the granite bedrock across most of the island is a veneer of Quaternary sands, which gives rise to

dark acid sandy soils with a pH of about 4 (Lees 1976, Jennings 1976, Richley 1984). Quaternary coastal calcareous sand deposits form extensive dune systems, which have been recently stabilised on the west and southwest of the island (Richley 1984). These sands have a pH of between 8 and 9 (Lees 1976).

### Topography

Low hills exist in a band around the east of the island from the northeast to the southwest (fig. 2). The three highest hills, from which the island is named, are North Hummock 160 m a.s.l., Middle Hummock 100 m a.s.l. and South Hummock 237 m a.s.l. The hills border a broad, flat plain in the centre of the island. The drainage from this plain is blocked by the extensive dune systems to the west, resulting in the development of swamps and lagoons (pl. 1).

## VEGETATION COMMUNITIES

### Scrub on Acid Sands

This formation covers 3976 ha or 54% of the island and is the most common and widespread vegetation type. The typical height of this scrub is between 4 and 5 m and it comprises a dense thicket, usually dominated by *Leptospermum scoparium*, *Melaleuca ericifolia* and *Banksia marginata*, but also including *M. squarrosa*, *Acacia mucronata*, *A. verticillata* and *Leucopogon australis*. *Eucalyptus nitida* is often emergent (pl. 2). Other species sometimes occurring in the lower to mid layers are *Pimelea linifolia*, *Epacris impressa*, *L. ericoides* and *Dillwynia glaberrima*. Dieback of *Pteridium esculentum* is usually very evident at this stage of succession.

This 4–5 m high scrub results mainly from a widespread fire about 1960. Low, closed scrub/shrubland, which regenerated from the widespread fire of 1982, is evident everywhere with varying heights, depending on site

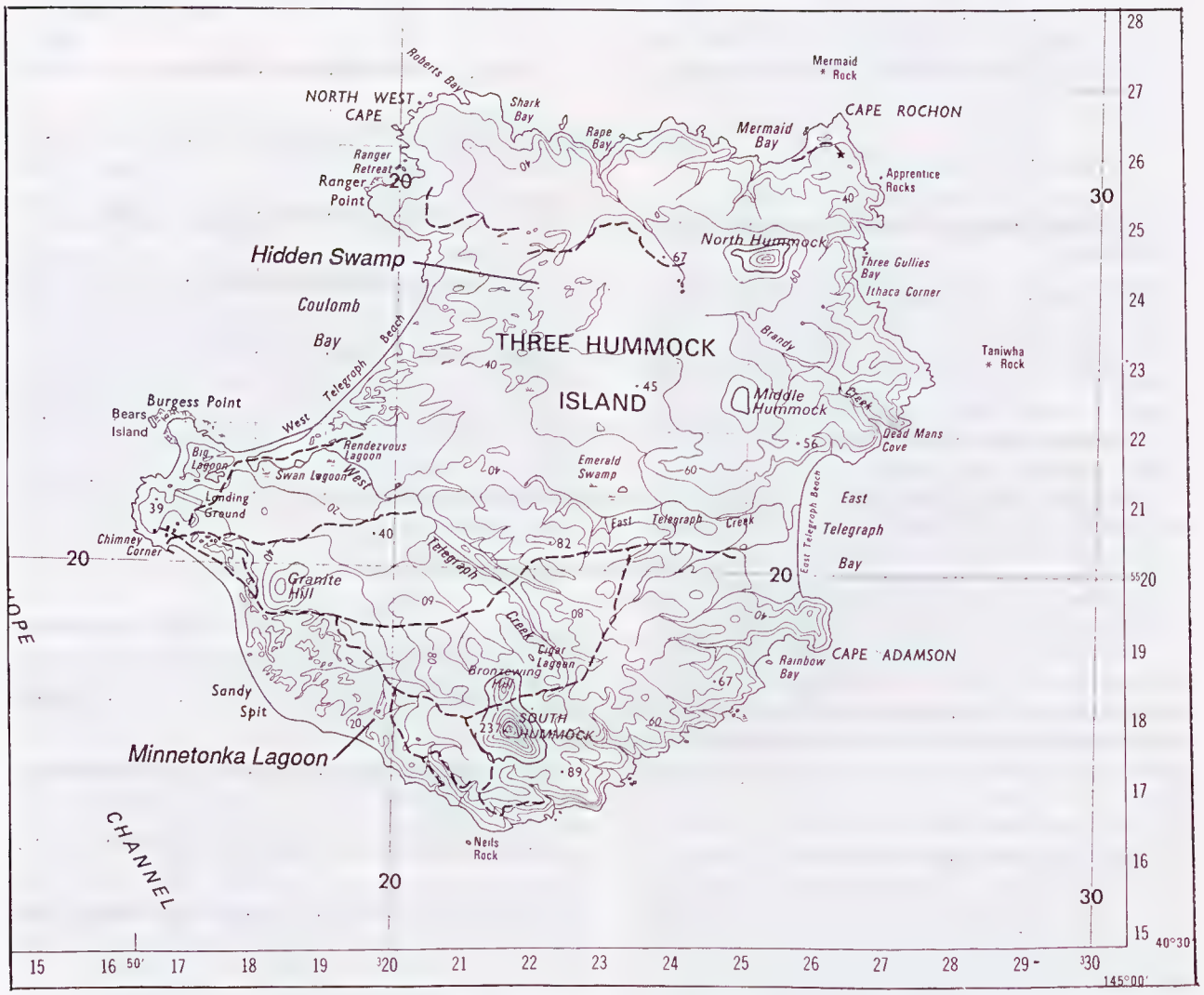


*FIG. 2 — Topography and locations mentioned in the text. The grid lines are 1 km apart.*

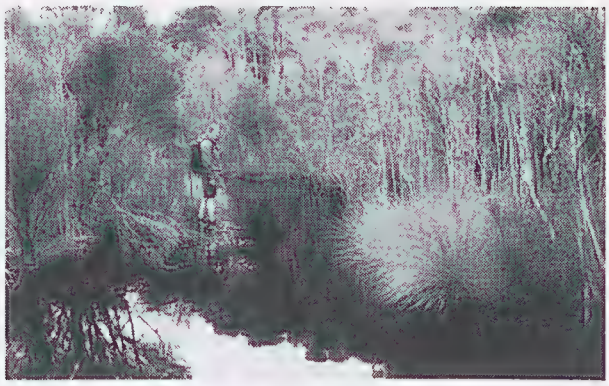

*PLATE 1*

*The eastern plateau surface declines in altitude to the west. A zone of wetlands occurs where drainage to the west is blocked by sandsheets on the coast. The wetlands are dominated by* Melaleuca ericifolia.

*PLATE 3*

*A swathe of heath about ten years old on acid sands. South Hummock is visible in the left distance.*

*PLATE 2*

Eucalyptus nitida *scrub near the Mermaid rookery hut. There is a gradation from grassy heath (with* Boronia anemonifolia, *bracken, and* Poa poiformis *in the foreground) to dense scrub, where* Leptospermum scoparium *and* Acacia verticillata *are codominant with the eucalypt.*

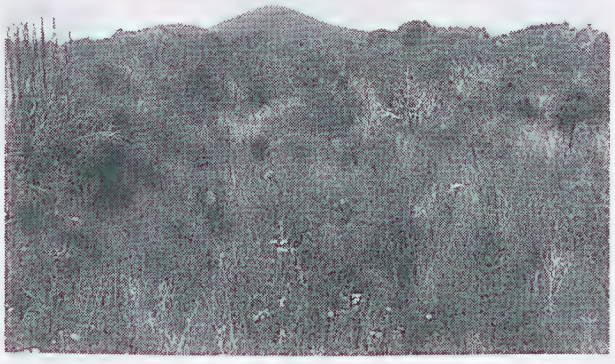

*PLATE 4*

*On the eastern plateau surface of the island, soils are peaty, siliceous and acid and support heath and shrubland. North Hummock is in the background.*

conditions but mainly between 2 and 3 m. The species diversity in the younger formation is only slightly higher. For example, in addition to the species mentioned above, there may also be *Aotus ericoides*, *Cassytha pubescens*, *Melaleuca squamea* and *Restio complanatus*. Comparing paired plots in similar vegetation resulting from the two fire ages, it is evident that an accumulation of brown fibrous peat (Ao horizon) up to 50 mm depth over the dark-grey mineral soil in the older (35 y.o.) formation is reduced to less than 10 mm, 13 years after the subsequent fire.

Most species in the scrub are present in the sedgeland/heath at least at trace levels. It is, therefore, apparent that all the heaths on the island on acid sands have the potential to develop into scrubs with the above species composition.

Burning the scrub vegetation results in different rates of post-fire growth, which apparently vary on the basis of soil drainage. The growth rates in the better drained sandy soils are rapid, and the vegetation returns to scrub in about ten years. Frequent firing is required to maintain species such as *Hibbertia procumbens*, *Epacris lanuginosa*, *Sprengelia incarnata*, *Acacia suaveolens* and *Leucopogon collinus* for any length of time in the vegetation on these better drained sites. These sites do not support the more characteristic western Tasmanian sedgeland species, such as *Empodisma* sp., *Lepidosperma* spp. or *Lepyrodia* sp. The lack of recent burning in the drier parts of the island has resulted in the restriction of the drier heaths to relatively small areas, in comparison to the scrub and wet sedgeland heaths, which are maintained for longer periods in the absence of fire.

## Sedgeland/Heath

This formation occupies 81 ha or about 1% of the island, and comprises a subset of the scrub flora *Banksia marginata*, *Leptospermum scoparium*, *Melaleuca squarrosa*, *M. squamea*, *Leucopogon australis*, *Gahnia grandis* and *Epacris impressa* (pls 3, 4). Additionally, it includes typical sedgeland heath species, of which *Sprengelia incarnata*, *Dillwynia glaberrima*, *Empodisma minus*, *Patersonia fragilis*, *Restio complanatus*, *Hibbertia procumbens*, *Lepyrodia tasmanica*, *Bauera rubioides*, *Epacris lanuginosa*, *Selaginella uliginosa* and *Cassytha glabella* are the most widespread and characteristic. A number of species are locally common but geographically restricted in this flora, for example *E. obtusifolia*, *Lepidosperma filiforme*,

*Schoenus lepidosperma* and *H. prostrata*. This may be caused by environmental patchiness or intolerance to the range of past fire regimes experienced in many parts of the island. Others are faithful but only occasional: *Comesperma retusum*, *Xyris muelleri*, *Drosera peltata* and *Xanthosia dissecta*.

In the most poorly drained areas of the island with the exception of areas permanently flooded, acid peat soils have developed.

There are relatively few obligate seeders, and recovery after fire is rapidly achieved, mainly by resprouting. Growth rates are stunted in this environment but, where fire is excluded for long enough, the community succeeds to scrub, as described elsewhere in this study. The greatest species diversity is in heaths recently burnt, when species intolerant of shading are temporarily abundant; for example *D. pygmaea* and *Boronia parvifolia*. *Xanthosia dissecta* and *H. prostrata* were only found in the most recently burnt areas.

## Scrub on Calcareous Sands

This formation is restricted to wind-blown sands of marine origin, mainly occurring behind West Telegraph Beach and along the south coast. It comprises 428 ha, which is 6% of the island, but would have been more extensive in the past, since much of the native vegetation has been cleared for grazing sheep and cattle (pl. 5).

There is a distinctive set of species which characterise these alkaline sands. The dominant species of the scrub are *Leptospermum laevigatum*, *Banksia marginata* and *Leucopogon australis*. *Leptospermum laevigatum* is replaced by *L. scoparium* and *L. glaucescens* on the acid sands. A group of species with a high fidelity to calcareous sands includes *Myoporum insulare*, *Acacia sophorae* and *Olearia glutinosa*. These species may represent the components of a climax scrub–low closed forest vegetation.

The ridges have more depauperate understoreys, while swales are more apparently species-rich, possibly because of more reliable moisture availability together with leaching of nutrients from the dune profile. Apart from a whole suite of pasture and exotic species, which have invaded from the old pasture, other characteristic understorey species, though not totally faithful to the scrub on alkaline dune sands, include: *Senecio odoratus*, *Urtica incisa*, *Apalochlamys spectabilis*, *Olearia ramulosa*, *Actites megalocarpa* and *Carpobrotus rossii*. In swale areas, a grassy bottom of *Poa poiformis* with intertussock herbs often occurs, while the ground layer on the ridges is mainly compact leaf litter from the usually dense *L. laevigatum* scrub. Pendant mats of *Rhagodia candolleana* and *Tetragonia implexicoma* are prevalent in scrub which has not been burnt for some time. Herbs such as *Galium australe*, *Daucus glochidiatus*, *Apium prostratum*, *Dichondra repens* and *Hydrocotyle muscosa* are common in the ground layer.

Some areas of alkaline sands have been used as rookeries.

## Wetlands

Wetlands comprise 58 ha or <1% of the island. The main belt of wetlands occurs north to south on the landward side of the marine sands of the west coast, which block westward drainage. Emerald Lagoon is a major wetland, which collects drainage in the headwaters of East Telegraph Creek. Minor estuarine wetlands occur at the mouth of East Telegraph Creek and West Telegraph Creek.

The wetlands on the acid sands are freshwater but those nearer the west coast are more saline. The permanent lagoons within the calcareous sands have a higher diversity of wetland flora than either those on the acid sands or those that are ephemeral. For example, Big Lagoon was observed to have more than 20 species, including *Triglochin procera*, *Lemna disperma*, *Myriophyllum salsugineum* in the deepwater zone; then *Villarsia reniformis* (with *Myriophyllum*) and *Ranunculus amphitrichus* and *Eleocharis acuta* in the shallow zone within the boundary of the most reliable water level; then a fringing zone of mainly *Ranunculus*, *Isolepis subtillissima*, *Erythranthera* sp., *Eryngium vesiculosum*, *Cotula coronopifolia*, *Pratia surrepens* and *Limosella lineata*; then an outer zone of *Melaleuca ericifolia* scrub over a sparse ground cover of *Carex appressa*. *Juncus kraussii* is on the wind-exposed edge of the lagoon shore.

The *M. ericifolia* swamp (Hidden Swamp) at GR264264 is immediately behind the toe of the sand sheet and so would be expected to have similar nutrient levels and pH to that of Big Lagoon but, in contrast to Big Lagoon, the water here is intermittent. The vegetation at this site is a *M. ericifolia* tall open scrubland, having an understorey with patchy colonies of *Carex appressa* and other ground plants, such as *Lilaeopsis polyantha*, *Hydrocotyle hirta*, *Leptinella longipes*, *Aira* sp, *Lobelia alata*, *Pteris tremula*, *Agrostis aequata*, *Bromus diandra*, *Senecio hispidulus* and some *Gahnia trifida*.

The wetlands associated with the acid sands are notably depauperate in species, although this varies to some extent with size and water permanency. Intermittent wetlands have floors colonised by "damp" species and are fringed or occupied by *M. ericifolia* (and *M. squarrosa* to a lesser degree). The bases of large *Melaleuca* trees in the permanent water have a moss stocking above the water level, which supports a proliferation of *Schizaea fistulosa*. *Restio tetraphyllus* and *Gahnia grandis* are common and occur in the zone of most frequent or permanent inundation. Fringing these lagoons are usually dense scrub thickets with *Gleichenia microphylla*, *Melaleuca* spp., *Gahnia grandis* and *Empodisma minus*. The only plants recorded in the aquatic zone were *Utricularia lateriflora*, *Restio tetraphyllus* and *Cryptostylis subulata*. Smaller lagoons are fringed with *Lepyrodia*, which also dominates the swales in the sedgelands.

Emerald Swamp is the single largest swamp on the island; it is an acid paperbark swamp forest, which most closely fits the C3 Coastal swamp Forest classification of Pannell (1992), because it contains the prescribed dominants *M. ericifolia* and *Acacia melanoxylon* but almost none of the common species meant to typify the community, although other species are common (e.g. *Schizea fistulosa*) (pl. 6).

The melaleucas at Emerald Swamp are of similar diameter at breast height (dbh) and height to those at Hidden Swamp; therefore, presumably, both are of the same age since last fire. While there are differences in the permanency of water, some obvious floristic differences are apparently related to other edaphic factors, such as nutrients and pH. Both Big Lagoon and Hidden Swamp were rich in wetland or herbaceous species, whereas at Emerald Lagoon and other acid wetlands the flora of the aquatic zone was confined to a few species (all absent from the wetlands on the calcareous sands). Few terrestrial species were recorded. *Gahnia trifida* is replaced at Emerald Swamp by *G. grandis*, and *S. fistulosa*, abundant in Emerald Swamp, was not

*PLATE 5*
*View over the coastal scrub and grassland on the southwest of the island, with Hunter Island in the distance.*

*PLATE 7*
*The boundary between pasture on calcareous sands and eucalypt forest on acid sands. The only remnants of* Eucalyptus viminalis *forests in this locality southeast of Granite Hill are a few* E. viminalis *occurring on the edge of the calcareous sand sheet.*

*PLATE 6*
*Inside the* Melaleuca *forest in Emerald Swamp. At this locality, near the edge of the swamp, there are* Sphagnum *beds with numerous* Schizaea fistulosa.

*PLATE 8*
Eucalyptus nitida *woodland on the eastern flank of North Hummock.* Pomaderris *forms a patchy mid layer and bracken comprises a dense understorey.*

recorded from Hidden Swamp or the other wetlands on the calcareous sands.

Some lagoons have dried up. Minnetonka Lagoon is the most remarkable example of these. This lagoon is blocked by sand dunes, which were cleared late in the 1800s for pasture (R. Alliston, pers. comm.). Its history is not recorded, but the presence of dead stags of tea-trees (either *Melaleuca* or *Leptospermum*) suggests that it was a swamp forest in the past. Since the death of the trees prior to 1951 (R. Alliston, pers. comm.), there has been some severe erosion on the upper slopes of the basin, evidenced by the tree roots which are now 100–200 mm above the ground surface. An accumulation of sands has been deposited in the dry basin floor, and these support the pioneer species *Carpobrotus rossii*, *Centrolepis monogyna*, *Gnaphalium* spp, *Sagina apetala*, *Crassula sieberana* ssp. *sieberana* and *Schoenus*. The herbaceous species are the only species to occupy the freshly accumulated sands on the upper margins of the basin but are replaced in importance by the shrubs *Olearia glutinosa*, *Melaleuca ericifolia*, *Senecio glomeratus* and *Apalochlamys spectabilis* on the basin floor. The absence of plants larger than 1 m in height within the basin suggests recent fires or some other factor that has caused the vegetation to be no older than three years. Yet, the surrounding vegetation leading into the basin has not been burnt for at least 23–28 years (derived from nodal counts on *Banksia marginata*), plenty of time for plants of tree height to establish, and there are, at present, abundant tree seedlings throughout the basin floor.

## *Eucalyptus viminalis* Woodland and Forest

This vegetation type occupies 30 ha or <1% of the island. It is restricted to the marine coastal sands which have mostly been cleared for pasture. The *E. viminalis* forests appear to coincide very closely with the cleared pasture areas on the southern part of the island (pl. 7). It is not possible to check this entirely, but the boundary between the *E. viminalis* community on the sand and *E. nitida* communities on the acid granite soils were found in three situations where a continuous eucalypt cover still existed across these substrates.

The *E. viminalis* forests and woodlands tend to be more open and less tangled than the other eucalypt communities on the island. They are grassy and shrubby and have a relatively high species diversity. At site 52 (GR207169), umbrageous *E. viminalis* has a patchy mid layer of *Myoporum insulare*, *Melaleuca ericifolia*, *Acacia melanoxylon* and *A. verticillata* with *Olearia glutinosa* and *Leptospermum laevigatum* as minor components. The understorey includes

*Pteridium esculentum*, dense *Poa poiformis*, *Dianella tasmanica*, *Pterostylis* sp., *Oxalis corniculata*, *Hydrocotyle hirta*, *Cerastium glomeratum*, *Viola hederacea*, *Bursaria spinosa*, *Luzula flaccida*, *Monotoca glauca*, *Drosera peltata* and *Isolepis nodosus*.

A few scattered *E. viminalis* also occur on deeper soils around the eastern side of South Hummock where they occupy forests dominated by *E. nitida* and *E. ovata*.

## *Eucalyptus nitida* Forests

*Eucalyptus nitida* occurs extensively over the island on the acid sands. In all, these forests occupy 1857 ha or 25% of the island's vegetation. *E. nitida* occurs as scattered individuals emergent within the wet sedgeland heath, as an emergent at varying densities over the *Leptospermum scoparium–Banksia marginata* scrub and as a forest dominant of wet eucalypt forest where it may co-occur with *E. brookeriana* and *E. viminalis*. The latter forests occur on the deepest loam soils, which have developed in areas topographically protected from high fire frequencies. They occur on the southern and eastern slopes of South Hummock and North Hummock and in the deep gullies on the island.

Trees can reach up to 35 m, but are typically much shorter. The understorey of the taller forests varies from pure *Olearia argophylla* patches, with only *Pteridium* and *Coprosma* in the ground layer, to a diverse open scrub layer of *Acacia* species, *Melaleuca ericifolia*, *Bursaria spinosa*, *Monotoca glauca*, *Cyathodes juniperina* and *Leucopogon australis*, and a lower ground layer of *Pimelea linifolia*, *Coprosma quadrifida* and the climber *Clematis aristata*. The ground is covered with a thick layer of litter, but a variety of herbs occur sparsely, including *Geranium potentilloides*, *Drymophila cyanocarpa*, *Dianella tasmanica*, *Pterostylis* sp. and other orchids. Along the drainage lines, *Histiopteris incisa* and *Gahnia grandis* are more frequent and the ferns *Dicksonia*, *Phymatosorus* and *Pteris tremula* occur only rarely.

On the eastern slopes of North Hummock (pl. 8), *Pomaderris apetala* replaces *Olearia argophylla* as the major understorey dominant, and the ground layer includes *Lepidosperma elatius*.

In more frequently burnt and recently burnt areas, the ground layer includes *Poa poiformis*, which is typically sparse but can form a dense cover in places. *Boronia anemonifolia* also occurs in recently burnt forests and survives at least 25 years.

A transition exists between *E. nitida* forests and scrub communities, the eucalypts reducing in height as they approach more frequently burnt and recently burnt areas, and as they approach the coast. They are replaced by *Melaleuca ericifolia* tall scrub before the coast is reached, dropping out more quickly on the exposed ridges but getting closer to the coast in the gullies. They are also replaced by *M. ericifolia* swamp forest in areas of permanent water logging.

In the absence of fire, these forests are likely to replace the scrub communities. They are also likely to become progressively more open with time, given the relatively short life spans of many of the component scrub species: *Acacia verticillata* is likely to live only 50 years and the other *Acacia* species less than 130 years. Some examples of continuous regeneration were evident in older *E. nitida* forests with *M. ericifolia* scrub understoreys. In such forests there is sufficient light generated by canopy gaps to allow *M. ericifolia* seedlings to establish and grow to maturity. This has been observed in the swamp forests of northwestern Tasmania (Gibson *et al.* 1987).

## Rookeries

The area occupied by seabird rookeries has not been determined but the locations of the larger rookeries are shown in figure 3. Most rookeries have been cleared by firing. The fertile soils are usually sandy and high in phosphates, making them alkaline whether they occur in granite or marine-derived sand. Some rookeries are intact and support dense vegetation dominated by *Poa poiformis* tussock grassland or *Carpobrotus rossii–Tetragonia implexicoma–Rhagodia candolleana* succulent mat herbfield. Plants requiring ground disturbance are common. These include mainly native composite herbs but also many exotic species. The native species include *Apalochlamys spectabilis*, *Senecio odoratus*, *S. glomeratus*, *S. hispidulus*, *Urtica incisa* and *Sambucus gaudichaudiana*. There is a convergence of species composition in rookeries on old marine (alkaline) sands and granite-derived sands.

A few rookeries in more inaccessible parts of the coast occupy wooded habitat. An example of one of these is at site 46 (GR256191), where *Melaleuca ericifolia* scrub occurs with some open patches with *P. poiformis* tussock grass cover of 80% projective foliage cover. The soils are sandy loam. *Rhagodia candolleana* occurs in patches, and other species are *Senecio* spp., *Hydrocotyle*, *Parietaria debilis*, *T. implexicoma*, *Sambucus gaudichaudiana*, *U. incisa*, *Carex appressa* and *Eucalyptus nitida*.

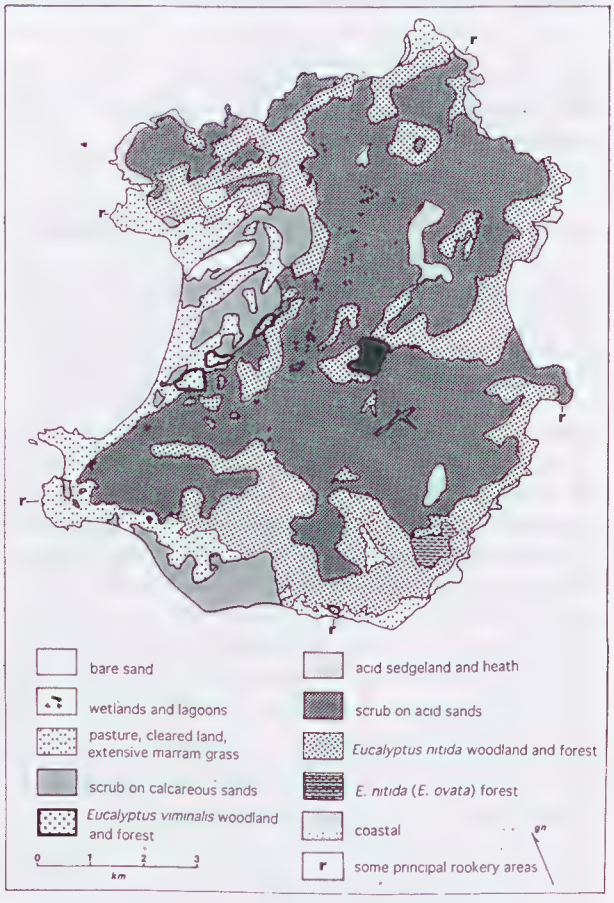


*Fig. 3 — Vegetation of Three Hummock Island.*

## Pasture and other Modified Areas

Much of the stabilised calcareous sand dunes have been modified for use as pasture for cattle and sheep grazing. The mapped area comprises 688 ha or 9% of the island and includes extensive areas dominated by *Ammophila arenaria,* which in the past have largely been maintained by fire for grazing purposes. Some areas have been cleared and sown with introduced species, top-dressed with superphosphate, cobalt and copper. *Cerastium, Trifolium,* various introduced grasses and a rich variety of other exotic species dominate these areas. Areas of the sand dunes that have been cleared and fired, but not top-dressed or sown with improved pasture species, are now dominated by *Poa poiformis* on the exposed slopes and on the lee of the slopes by *Pteridium* and *Isolepis nodosus* co-dominant with *Poa poiformis.* A rich variety of native and introduced herbs are characteristic of this vegetation. Native species include *Ajuga australis, Geranium solanderi, Urtica incisa, Dichondra repens, Schoenus apogon, Crassula sieberana* and *Apium prostratum.* Common exotics include *Cirsium arvensis, Hypochoeris radicata, Acetosella vulgaris, Bellis perennis, Oxalis* species, *Holcus lanatus, Trifolium, Cotula coronopifolia, Calandrinia calyptrata* and *Arctotheca calendula.*

Areas no longer being heavily grazed are now being invaded by pioneering shrubs, such as *Cassinia aculeata* with wind-dispersed seed, *Melaleuca ericifolia,* which, presumably, is also wind-dispersed, and species with long-lived seed stored in the soil, like *Acacia melanoxylon* and *A. verticillata.*

In addition to the pastures, three other areas have been cleared for airstrips, the one at Chimney Corner doubling as a grazing paddock. The area around the houses has garden plants.

## Coastal Vegetation

Coastal vegetation comprises sand dune grasslands and shrublands, ephemeral herblands, sedgy and grassy herbfields on sand or peat, coastal heath, shrublands, scrub and grassland. Coastal vegetation as mapped includes low formations directly influenced by coastal processes. This mapping unit comprises 122 ha or 2% of the island.

The area influenced by coastal processes will be larger on an island because of greater exposure to onshore winds from any direction.

The coastal environment on Three Hummock Island can be divided into sandy coasts and rocky coasts. About 10 km of sandy coast occurs, mainly behind East and West Telegraph Beaches and Sandy Spit. On East Telegraph Beach (GR258198), a zonation across a berm, swale and foredune was observed: beach:unvegetated >>> front and summit of berm: *Ammophila arenaria* (associated species - *Carpobrotus rossii, Daucus glochidiatus*) >>> rear of berm: *A. arenaria* (associated species — *Isolepis nodosus, C. rossii, Stackhousia spathulata, Actites megalocarpa, Ozothamnus turbinatus*) >>> swale: *O. turbinatus* (associated species — many herbs including *C. rossii, D. glochidiatus, A. megalocarpa, Lepidosperma gladiatum, Dichondra repens, S. spathulata* and some herbaceous weeds) >>>foredune slope: *Ammophila arenaria* comprises a third of the ground cover and the remainder is patches of various shrubs such as *O. turbinatus, Correa backhousiana, Myoporum insulare* and *Leucopogon parviflorus. Lepidosperma gladiatum* is a major dominant in this zone.

The zonation along the more exposed West Telegraph Beach differs from that at East Telegraph. Many zonal sequences exist along the beach and, although a uniform sequence could theoretically evolve along the beach in the absence of disturbance, this will not happen because of the dynamic nature of the habitat, which is subject to frequent (more so than the east coast) disturbances, such as storm events (having various effects on sand erosion and deposition, and salt accumulation), fires and wind erosion. Therefore, many stochastic and episodic events cause a scrambling of vegetation patterning. However, logical zonal sequences occur based on species responses to environmental factors.

Smaller beaches on the sheltered southern and south-eastern part of the island are more protected from storms and also fire, both because of steep slopes to the rear of the beaches and also because they are less likely to be used as frequent boat anchorages, which are often associated with onshore fires. On these smaller beaches, there is a very dense shrubbery of *C. backhousiana,* with *Melaleuca ericifolia* to landward. The *Melaleuca* forms a narrow discontinous zone around the steeper parts of the coast between the distinctive zone of coastal species and the eucalypt-dominated formations (pl. 9).

Many microhabitats occur around the coast. Small herbfields and grassy herbfields occur on patches of perennially wet ground at groundwater soaks or at the mouth of streams. At the northern end of West Telegraph Beach, for example, there is a sedgy herbfield in a damp swale. This herbfield forms a complete ground cover comprising *Carex breviculmis, C. appressa, Lilaeopsis polyantha, Plantago coronopus, Isolepis nodosus, Apium prostratum, Selliera radicans, Samolus repens, Schoenus nitens, Hydrocotyle muscoides, Gratiola latifolia* and *Eleocharis acuta.*

The rocky granite shores present a diversity of microhabitats with varying levels of shade, exposure, moisture availability and susceptibility to invasion by exotics. Shady moist crevices may contain *Asplenium obtusatum* or *Lobelia alata.* Gravel chutes or rocky crevices at high-water mark may have *Sarcocornia quinqueflora.* The tops of large boulders or tors may have bird-dispersed species such as *Alyxia buxifolia, Cyathodes juniperina* and the exotic

*PLATE 9*

*A small bay on the east coast, south of Cape Rochon.* Eucalyptus nitida *scrub is visible on the skyline behind a coastal belt of* Melaleuca ericifolia *dominated scrub. Wind pruning of the scrub is evident at the head of the bay.* Stipa stipoides *tussocks are visible at the edge of the beach.*

*Coprosma repens*. On headlands and exposed rocky shores, *Stipa stipoides* frequently dominates a zone, which may be mainly bare rock and with plants in crevices and on small peaty lenses. These may include *Samolus repens*, *Sarcocornia quinqueflora*, *Luzula flaccida*, *Juncus kraussii* and *Limosella lineata*. Where *Correa backhousiana* and *Cyathodes juniperina* occur together, the latter can be highly wind pruned, while *Correa backhousiana* does not become wind pruned at all and its growing tips seem to be unaffected by salt winds relative to *Cyathodes*.

## THE FLORA

There are 289 taxa of vascular plants from 80 families recorded for the island. There are 60 introduced species. Only two species are endemic to Tasmania. The island has a similar number of plant species to Clarke Island (8230 ha) in Eastern Bass Strait, which is a similar size to Three Hummock Island and a similar distance from the mainland of Tasmania. Clarke Island has 266 native species (Harris & Reimer 1994). The compositions of their respective floras differ. The northwestern islands, in general, appear to have a flora with stronger Tasmanian affinities (J.B. Davies, pers. comm., S. Harris, pers. obs., Hope 1978). This could be explained by the relatively greater isolation from the mainland of King Island and the distance between King Island and the islands of the Hunter Group. There is no archipelago of islands connecting mainland Australian and Tasmanian floras such as occurs in Eastern Bass Strait, where dispersal may be more easily affected between the islands of the Curtis, Hogan, Kent and Furneaux Groups. Clarke Island exists close to Cape Barren Island, which is much larger than the nearest islands to Three Hummock. The deepest part of Bass Strait separates King Island from Cape Otway (Blom 1988). Blom suggested that during the last glacial, Bass Strait was replaced by a saline lake bounded by a ridge to the east (Bassian Rise) and a lower ridge to the west (King Island/Mornington Peninsula Basement Ridge). As the sea level rose during the post-glacial transgression, the deeper sill north of King Island was flooded first about 10 000 years BP. The Bassian Rise was flooded at approximately 8000 years BP. Western Bass Strait has provided a greater barrier to latitudinal plant dispersal than Eastern Bass Strait because of the greater length of separation between Victoria and King Island.

In terms of island bigeography theory (MacArthur & Wilson 1967), the number of species recorded is consistent with the species area relationship (fig. 4). An interesting comparison can be made between the islands of similar size in figure 4. Schouten Island has more species than the islands in the group of nearest size. Three Hummock and Hunter Islands are poorer in species, whereas Clarke Island is intermediate in richness. Both Clarke and Schouten Islands have greater habitat diversity. Schouten Island has the greatest variety of substrate types, including dolerite, and is situated in an identified centre of endemism

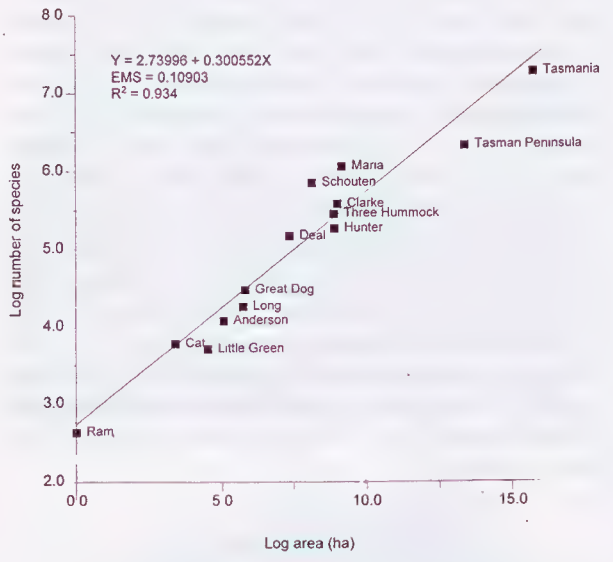


*Fig. 4 — Regression of number of plant species on area from 13 islands in Bass Strait and eastern Tasmania. Values for Tasman Peninsula and Tasmania are included for comparison.*

TABLE 1
**Geographical and floristic comparisons: Three Hummock Island and Clarke Island**

| Attribute | Three Hummock Island | Clarke Island |
|---|---|---|
| area (ha) | 7284 | 8230 |
| latitude | 40°25' | 40° 31' |
| longitude | 144°55' | 148°15' |
| av. ann. rainfall | 939 mm | ≈616 mm* |
| mean no. of annual raindays | 208 | ≈133* |
| temperature: | | |
| av. summer min. and max. (Feb.) | 13–20°C | ≈14.6–20°C* |
| temperature: | | |
| av. winter min and max. (July) | 8–12.9°C | ≈8.2–12.8°C* |
| total no. of native vascular plants recorded | 229 | 266 |
| no. of introduced plants | 60 | 42 |
| no. of native plant families | 72 | 75 |
| no. of Tasmanian endemic plants | 2 | 6 |
| plant spp. at southern limit | 0 | 6 |

* Records obtained from nearby Swan Island.

(Kirkpatrick & Brown 1984), which is known for the particular association of endemics with the dolerite substrate. The island also has much greater relief than Clarke and Three Hummock Islands, thereby allowing more habitat niches to be sustained.

Mediterranean climate landscapes in the Southern Hemispere such as the South West Botanical Province of Western Australia and the Cape Fynbos of South Africa have a higher floristic diversity than areas with cool temperate climates (Nelson 1981). Although Three Hummock Island and Clarke Island share equivalent temperature ranges, Clarke Island is considerably drier (table 1), with greater evapotranspiration due to more cloud-free days and a climate which approaches the characteristics of a Mediterannean climate.

It is clear that both Hunter and Three Hummock Islands are relatively poorer in species than the islands of eastern Tasmania. Both Hunter and Three Hummock Islands have low geological diversity. Hunter Island is mostly quartzite with old, unconsolidated sands. Three Hummock Island, in addition, is very uniform in habitat with only two major substrate types: acid sandy and gravelly granite-derived substrates and alkaline sands of marine origin, as well as a small number of habitat types. In the past, the basalt has been cleared, cultivated and ploughed. Clarke Island is only slightly more diverse, containing Silurian metasediments, granite, calcareous marine sands and calcarenite. Even Deal Island, which is smaller than Three Hummock Island and Hunter Island, and is more remote from larger land masses, has a relatively rich flora in comparison to the Hunter Group Islands. Tasman Peninsula (Brown & Duncan 1989) and Little Green Island (S. Harris and A.M. Buchanan, pers. obs.) are shown to be species-poor in relative terms. Looking further than the high correlation of species numbers and island size, explanations for the relative numbers of species amongst these islands may be found in any number of other factors, such as climate, relative proximity to other islands and land masses, degree of human modification, time since isolation, and proximity to centres of endemism and palaeogeographic refugia. Furthter work is necessary on data from all Tasmanian offshore islands before the role of these factors is clarified.

Calcarenite (or Tertiary limestone) is absent from Three Hummock Island but occurs on King Island. Yet only on limestones in eastern Bass Strait do southern Australian Mediterranean climate species, such as *Threlkeldia diffusa* and *Zygophyllum apiculatum* occur. Nor do the Eremean elements, which occur in eastern Bass Strait (Harris & Davis 1995), occur in western Bass Strait. These elements include *Sicyos australis*, *Gyrostemon thesioides*, *Frankenia pauciflora*, *Ixiolaena supina*, *Lavatera plebeia* and *Calytrix tetragona*. Some drought tolerant and widespread species are conspicuously absent in western Bass Strait (Harris & Davis 1995). The drought tolerant *Callitris rhomboidea*, for example, is absent from western Bass Strait, even though it occurs at Cape Nelson (fig. 1) on the southwestern coast of Victoria. Additionally, the widespread (in warm southern coastal Australia), drought-hardy, exotic grasses *Catapodium rigidum*, *Parapholis incurva* and *Hainardia cylindrica*, similarly widespread in the Furneaux Group, are not known from western Bass Strait islands.

It is possible that more detailed floristic and climatic analyses will show that the eastern extremity of the southern Australian Mediterranean climate envelope takes in northern Bass Strait but widens towards the east with a bifurcation at the eastern extremity of Bass Strait. The northern arm extends up the extreme eastern coast of Victoria around Croajingalong National Park, and the southern arm includes the extremities of northeastern Tasmania and central eastern coastal Tasmania. Where this climatic envelope is coincident with siliceous soils, there are species belonging to otherwise South West Western Australia Botanical Province genera which fit within the eastern extremes of this environmental envelope. *Conospermum taxifolium* sensu lato (Proteaceae) is a good example. It occurs on sandy substrates from Freycinet Peninsula to St Helens and at Croajingalong National Park.

Comparing the species list from this study with that of Cameron (1984) from the heathland and scrub around Ordnance Point in northwestern Tasmania, indicates that Three Hummock Island flora is a depauperate subset of the northwestern Tasmanian coastal and near coastal flora.

## GENERAL DISCUSSION

The vegetation of Three Hummock Island has changed a lot since the cessation of extensive grazing activity on the island in the 1970s. Areas that were formerly open shrubland and grassland are now heavily colonised by scrub, mostly dominated by *Leptospermum laevigatum*. These areas provided the main grazing runs for cattle and were burned every year (J. Alliston, pers. comm.). On the siliceous acid sands and gravels over the granite, extensive fires maintained the vegetation as heath and sedgeland. *Eucalyptus nitida* is heavily coppiced and the diameter of the underground lignotuber is estimated in some cases to be up to 3 m in diameter. This eucalypt can survive a high fire frequency although it is an element of the taller eucalypt forests in the more fire protected parts of the island.

The most extensive fires in recent times occurred in 1982 and burnt across most of the island. Subsequent fires in 1984 "burnt out country which was missed in the 1982 fires" (R. Alliston, pers. comm.). The areas of taller eucalypt forest and Emerald Swamp were missed by these fires, but elsewhere the counting of growth nodes on *Banksia marginata* most often gave ages consistent with germination following fires in 1982 or 1984. On the sand plains behind West Telegraph Beach in 1976, there was extensive *Banksia* (and *L. laevigatum*) savannah shrubland which, since the cessation of grazing, has been colonised in the intervening spaces by regrowth comprising mainly *Banksia* but also including *L. laevigatum*, *Leucopogon australis* and *Olearia glutinosa*. The older *Banksia* trees are now 8 m tall. In one locality near the south coast, banksias of this height with a dbh of approximately 0.3 m gave inferred ages of around 40 years, where they were associated with a small patch of *E. viminalis* (0.20–0.25 m dbh, 8 m ht). Remnants of bush with inferred ages between 35 and 40 years old were encountered in various places, indicating extensive major fires somewhere between 1955 and 1960.

The exotic species recorded are mostly of agricultural origin and are typically grasses or clovers sown in developed areas, as well as ubiquitous weeds such as *Sonchus oleraceus*, *Cerastium glomeratum* and *Hypochoeris* spp. Around the buildings at Chimney Corner are old shelter tree plantings these mainly consisting of *Cupressus macrocarpa*, *Pinus radiata* and *Araucaria heterophylla*. *Lycium ferocissimum*, which was probably introduced as a windbreak has now

grown into thickets near the homesteads. An exotic tree grows at the Spring (*Salix* sp.). On the coast, *Senecio elegans*, *Euphorbia paralias* and *Ammophila arenaria* are the most striking introductions. *Senecio elegans* is more firmly established on the dunes of the western side of Three Hummock Island than anywhere else in Tasmania. Apart from growing occasionally on the strand line, the best development was observed to be on the north faces of dunes, especially in the disturbance zone around penguin burrows. The long-term effect of this introduction on native plant communities (at present it occurs amongst marram grass) is not known, but certainly the common name "elegant groundsel" is justified by the blaze of purple in early October. Marram grass (*A. arenaria*) occurs around the coast, effectively stabilising the youngest dunes at Chimney Corner and the berm and primary dune face at East Telegraph Beach.

## Vegetation Management

### Weeds

Weeds have been introduced over a long period of occupation of the island. Most of the weeds are concentrated around rookeries, where soil fertility and ground disturbance is maximised. The pasture grasses and associated weeds are found throughout the calcareous sandy areas which were preferentially cleared for pasture development. The coastal zone is exposed to sea-borne seed introductions (e.g. *Euphorbia paralius*). Weed control on the island would be expensive. Therefore, only those which pose a pernicious threat to nature conservation values should be targetted for control or eradication.

The establishment of *E. paralius* on the coast should be prevented. It is capable of aggressive colonisation of berms, foredunes and coastal herbfields, and has the potential to displace native species, particularly in the latter habitat. The seed source for these plants is likely to come from both the west and the east (see Harris & Kirkpatrick 1996) according to seasonal sea current flows. Establishment in this nature reserve would provide a reservoir of propagules which could invade much northwestern and western coastline.

The thistles *Carduus pycnocephalus* and *Cirsium vulgare* are prevalent in Ranger Rookery, where they form dense patches. The Ranger Rookery had been burnt more recently than any others. Burning the rookeries will encourage weeds such as thistles. Rookeries do not need to be burned at all. They can exist in association with dense tussock grass or in a shrubby or scrub understorey.

The concentration of exotics around the buildings at Chimney Corner need not be a management problem. African Boxthorn (*Lycium ferocissimum*) is the exception. Planted on many Bass Strait islands last century, it was an excellent wind break. If left uncontrolled it can spread and form large patches of impenetrable scrub and completely suppress other vegetation. Birds spread the seeds, which exacerbates the problem.

### Plant dieback

Symptoms consistent with cinnamon fungus (*Phytophthora cinnamomi*) mortality were observed in scattered small patches on the island.

Even if the fungus was determined to be present on the island, it is difficult to envisage appropriate measures to prevent its spread or to see whether control of spread would have any significant effect on the vegetation. There is an apparently low diversity of plants on the island which are susceptible to the fungus at the population level. It is possible that the fungus may have already run its course on the island and depleted populations of susceptible plants such as *Epacris lanuginosa* in some habitats.

## Fire Management

The purpose of fire management is to maximise flora diversity and long-term survival of component species. It is clear that the island has been dominated by scrub vegetation for at least as long as the island has been known by Europeans. Fire is required as part of the management regime for the island, because most of the communities require fire. We suggest some areas should remain unburnt for long periods. Fire exclusion areas should include the rookeries, much of the coastal vegetation, wetland and wetland perimeter vegetation and some patches of taller forest and dune scrub. A fire management plan is required for the island.

## ACKNOWLEDGEMENTS

We dedicate this paper to Commander John Alliston and Eleanor Alliston and their family, residents of Three Hummock Island since 1951, who originally advocated the purchase and reservation of the island by the Government, as a nature reserve. We thank Alex Buchanan and Dennis Morris of the Tasmanian Herbarium for checking our species identifications and identifying many of the difficult specimens. We also acknowledge the assistance of Neville Walsh for checking through the Melbourne Herbarium collection for specimens from Three Hummock Island. Dr Irynej Skira and Dr Adrian Pyrke assisted in various ways.

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(accepted 12 November 1996)

## APPENDIX
### Higher Plant Census for Three Hummock Island

**Vouchers and other records:**
HO = Voucher lodged at the Tasmanian Herbarium, Hobart;
MEL = Voucher exists at the National Herbarium of Victoria, Melbourne.
Where a taxa was not recorded by ourselves but by others it is marked as follows:
*1 Recorded by Kirkpatrick & Harwood 1981
*2 Recorded by P. Wells (Kirkpatrick & Harris 1995)
*3 Recorded by R. Gunn in 1844, H. Atkinson 1888, D. Lang 1979 (Ziegeler *et al.*1996, Curtis 1979).

**Conservation status codes** (source: Flora Advisory Committee 1994):
R= Listed as rare at a national level (Briggs & Leigh 1988); V=Vulnerable to extinction in Australia;
r = Rare but not extinct, endangered or vulnerable taxa, where:
r1 = Rare taxa that have a distribution in Tasmania that does not exceed a range defined by a square measuring 100 X 100 km;
r2 = Rare taxa that occur in 20 or fewer 10 X 10 km Australian Map Grid Squares in Tasmania;
r3 = Rare taxa that do not fit r1 or r2, but which have very small and/or localised populations wherever they occur in Tasmania.

**Distribution codes :** i= introduced; EN= endemic to Tasmania (source: Buchanan 1995).

**Community types:**
1 = *Eucalyptus nitida* forest
2 = Scrub on acid sands
3 = Sedgeland heath
4 = Acid wetlands
5 = Calcareous wetlands
6 = Calcareous grasslands
7 = Calcareous scrub
8 = *Eucalypus viminalis* forest
9 = *Melaleuca* swamp forest
10 = Coastal vegetation
11 = Rookery vegetation
12 = Pasture
13 = Horticultural plantings

**Species abundance codes:** r= rare; o=occasional; c= common.

| | Where record-ed | Status/ distri-bution | Community Types | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| ***DICOTYLEDONAE*** | | | | | | | | | | | | | | | |
| AIZOACEAE | | | | | | | | | | | | | | | |
| *Carpobrotus rossii* | HO | | | | | | r | r | | | | c | c | | |
| *Tetragonia implexicoma* | HO | | o | | | | | o | o | | | c | c | o | |
| *T. tetragonioides* | | | | | | | | | | | | c | c | o | |
| APIACEAE | | | | | | | | | | | | | | | |
| *Apium prostratum* | HO | | | | | | o | r | | | | c | o | o | |
| *Centella cordifolia* | *1 | | | | | | | o | | | | | | | |
| *Daucus glochidiatus* | HO | | | | | | | o | | | | c | c | o | |
| *Eryngium vesiculosum* | HO | | | | | | c | | | | | | | | |
| *Hydrocotyle hirta* | HO | | c | c | | | r | c | | c | o | c | c | c | |
| *H. muscosa* | HO | | | | | | c | c | | | o | r | | r | |
| *Lilaeopsis polyantha* | HO | | | | | | o | | | | | r | | | |
| *Xanthosia dissecta* | | | | | r | | | | | | | | | | |
| APOCYNACEAE | | | | | | | | | | | | | | | |
| *Alyxia buxifolia* | HO | | | | | | | | | | r | o | | | |
| ASTERACEAE | | | | | | | | | | | | | | | |
| *Actites megalocarpa* | HO | | | | | | | o | | | | o | o | o | |
| *Apalochlamys spectabilis* | HO | r2 | | | | | r | | | | | o | c | r | |
| *Arctotheca calendula* | HO | i | | | | | | c | c | | | | | c | |
| *Bellis perennis* | HO | i | | | | | | | | | | | | c | c |
| *Brachyscome diversifolia* | HO | | | | | | | | | | | r | | | |
| *Carduus pycnocephalus* | HO | i | | | | | | o | | | | | | o | |
| *Cassinia aculeata* | HO | | | o | | | | c | | | o | | o | o | |
| *Chrysocephalum apiculatum* | MEL | | | | | | | r | | | | | | | |
| *Cirsium arvense* | HO | | | | | | | c | o | | | o | o | c | |
| *C. vulgare* | HO | i | | | | | | o | | | | | | | |
| *Cotula australis* | HO | | | | | | | o | | | | | o | | |
| *C. coronopifolia* | HO | i | | | | | c | c | | | | c | | | |
| *C. vulgaris* var. *australasica* | | | | | | | | r | | | | | | | |
| *Gnaphalium collinum* | HO | | | | r | | | c | | | | c | | | |
| *G. indutum* | HO | | | | | | | | | | | o | | | |

Appendix cont.

| | Where recorded | Status/ distribution | Community Types | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| *Gnaphalium* sp. | HO | | | | | | | r | | | | r | | | |
| *Hypochoeris radicata* | HO | i | c | o | | | | c | c | | o | o | o | c | o |
| *Lagenifera stipitata* | HO | | r | | | | | | | r | | r | | | |
| *Leontodon taraxacoides* | HO | i | o | | | | | | | | | | | | |
| *Leptinella longipes* | *1 | | | | | | o | | | | | | | | |
| *Leucophyta brownii* | HO | | | | | | | | | | | o | | | |
| *Olearia argophylla* | HO | | o | | | | | | | o | | | | | |
| *O. glutinosa* | HO | | r | | | | r | | o | o | | o | o | | |
| *O. lepidophylla* | HO | | | | | | r | | | | | o | | | |
| *O. phlogopappa* | HO | | r | | | | | | o | | | | | | |
| *O. ramulosa* | HO | | r | | | | r | | | | r | o | | | |
| *Ozothamnus ferrugineus* | HO | | o | | | | | | | | | | | | |
| *O. turbinatus* | HO | | | | | | | o | | | | c | o | r | |
| *Pseudognaphalium luteo-album* | HO | | | | | | | | | | | o | o | o | |
| *Senecio biserratus* | *2 | | | | | | | | | | | | o | | |
| *S. elegans* | HO | i | | | | | | o | | | | o | o | | |
| *S. glomeratus* | HO | | | | | | | | | | | o | | | |
| *S. hispidulus* | HO | | | | | | o | | | | | o | o | o | |
| *S. lautus* | HO | | | | | | | | | | | o | | | |
| *S. minimus* | HO | | | | | | o | | | | | | | | |
| *S. odoratus* | HO | | r | | | | | | o | | | o | | | |
| *Sonchus asper* | HO | i | | | | | | o | r | | | o | c | c | |
| *S. oleraceus* | HO | i | | | | | | | r | | | o | c | c | |
| *Taraxacum* sp. | HO | i | | | | | | | | | | o | | | |
| *Vellereophyton dealbatum* | HO | i | | | | | | o | | | | o | o | o | |
| BRASSICACEAE | | | | | | | | | | | | | | | |
| *Cakile maritima* | HO | i | | | | | | | | | | o | | | |
| *Cardamine gunnii* | *1 | | | | | | | | | | | r | | | |
| *C. paucijuga* | HO | | | | | | | | | | | o | | | |
| *Lepidium flexicaule* | HO | R,r2 | | | | | | | | | | | | r | |
| *L. foliosum* | HO | | | | | | | | | | | | o | o | |
| *Rorippa* sp. | HO | i | | | | | | | | | | r | | | |
| CALLITRICHACEAE | | | | | | | | | | | | | | | |
| *Callitriche stagnalis* | HO | i | | | | | c | | | | | | | | |
| CAMPANULACEAE | | | | | | | | | | | | | | | |
| *Lobelia alata* | HO | | | | | | r | | | | | o | o | | |
| *Pratia irrigua* | *1 | | | | | | o | r | | | | | | | |
| *P. surrepens* | HO | | | | | | | o | | | | | | | |
| *Wahlenbergia littoricola* | HO | | | | | | | o | o | | | o | o | o | |
| *Wahlenbergia* sp. | HO | | | | | | | o | | | | o | o | o | |
| CAPRIFOLIACEAE | | | | | | | | | | | | | | | |
| *Sambucus gaudichaudiana* | HO | | | | | | | | r | | | o | c | r | |
| CARYOPHYLLACEAE | | | | | | | | | | | | | | | |
| *Arenaria leptoclados* | HO | i | | | | | | | | | | | | | o |
| *Cerastium glomeratum* | HO | i | | o | | | | c | c | r | | o | o | c | |
| *Colobanthus apetalus var apetalus* | HO | | | | | | | | | | | o | | | |
| *Minuartia mediterranea* | HO | i | | | | | | | | | | | r | r | |
| *Moenchia erecta* | HO | i | | | | | | r | | | | r | | | |
| *Petrorhagia velutina* | HO | i | | | | | | | | | | | r | r | |
| *Polycarpon tetraphyllum* | | i | | | | | | | | | | o | o | | |
| *Sagina apetala* | HO | i | | | | | o | o | | | | c | | o | |
| *S. maritima* | HO | i | | | | | | | | | | c | | o | |
| *Stellaria media* | HO | i | | | | | | | | | | | | o | |
| *S. multiflora* | HO | | | | | | | | | | | o | | | |
| *S. pungens* | HO | | r | | | | | | | | | | | | |
| CHENOPODIACEAE | | | | | | | | | | | | | | | |
| *Atriplex cinerea* | HO | | | | | | | | | | | o | | | |
| *Chenopodium glaucum* | *1 | | | | | | | | | | | o | | | |
| *Sarcocornia quinqueflora* | HO | | | | | | | | | | | o | | | |

Appendix cont.

| | Where recorded | Status/ distribution | Community Types | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| *Rhagodia candolleana* subsp. *candolleana* | | | r | | | | r | o | o | | | c | c | o | |
| CLUSIACEAE | | | | | | | | | | | | | | | |
| *Hypericum japonicum* | HO | | | | o | | | o | | | | | | | |
| CONVOLVULACEAE | | | | | | | | | | | | | | | |
| *Dichondra repens* | HO | | | | | | c | o | c | r | o | c | c | c | |
| CRASSULACEAE | | | | | | | | | | | | | | | |
| *Crassula decumbens* | HO | | | | | | | | | | | | o | | |
| *C. helmsii* | HO | | | | | | r | | | | | | | | |
| *C. sieberana* subsp. *sieberana* | HO | | | | | | o | o | r | | | c | c | c | |
| *C. sieberana* subsp. *tetramera* | HO | | | | | | | o | | | | o | | | |
| CUNONIACEAE | | | | | | | | | | | | | | | |
| *Bauera rubioides* | HO | | | | o | | | | | | | | | | |
| DILLENIACEAE | | | | | | | | | | | | | | | |
| *Hibbertia procumbens* | HO | | | | c | | | | | | | | | | |
| *H. prostrata* | HO | | | | r | | | | | | | | | | |
| DROSERACEAE | | | | | | | | | | | | | | | |
| *Drosera peltata* | HO | | | | o | | | | | o | | | | | |
| *D. pygmaea* | HO | | | | o | | | r | | | | | | | |
| EPACRIDACEAE | | | | | | | | | | | | | | | |
| *Acrotriche serrulata* | HO | | | | | | | | r | | | | | | |
| *Cyathodes juniperina* | HO | | | | | | | | | o | o | o | o | | |
| *Epacris impressa* | HO | | o | | o | | | | | o | | | | | |
| *E. lanuginosa* | HO | | | | c | | | | | | | | | | |
| *E. obtusifolia* | HO | | | | r | | | | | | | | | | |
| *Leucopogon australis* | HO | | c | c | o | | r | o | c | o | o | o | | | |
| *L. collinus* | HO | | | | c | | | | | | | | | | |
| *L. ericoides* | HO | | c | | | | | o | c | r | | | | | |
| *L. parviflorus* | HO | | | | | | | o | | | | o | | | |
| *Monotoca glauca* | HO | | c | c | o | | | o | c | c | | | | | |
| *Sprengelia incarnata* | HO | | | o | c | | | | | | | | | | |
| EUPHORBIACEAE | | | | | | | | | | | | | | | |
| *Amperea xiphoclada* | HO | | | | o | | | | r | | | | | | |
| *Euphorbia paralias* | HO | i | | | | | | | | | | r | | | |
| *E. peplus* | HO | i | | | | | | | | | | | | | o |
| *Phyllanthus gunnii* | HO | | r | | | | | | o | r | | | | | |
| FABACEAE | | | | | | | | | | | | | | | |
| *Aotus ericoides* | HO | | r | o | c | | | | | | | | | | |
| *Dillwynia glaberrima* | HO | | | | c | | | | | | | | | | |
| *Kennedia prostrata* | HO | | | | | | r | | | | | o | | | |
| *Pultenaea daphnoides* var. *obcordatum* | HO | | o | | | | | | | | | r | | | |
| *P. dentata* | HO | | | | | | | | | | | o | | | |
| *Trifolium cernuum* | HO | i | o | c | | | | o | o | | | c | c | c | |
| *T. subterraneum* | HO | i | | | | | | | | | | | | o | |
| *Vicia sativa* | HO | i | | | | | | | | | | | | r | |
| GENTIANACEAE | | | | | | | | | | | | | | | |
| *Centaurium erythraea* | HO | i | | | | | r | | | | | r | | | |
| GERANIACEAE | | | | | | | | | | | | | | | |
| *Erodium cicutarium* | HO | i | | | | | | | r | | | | | o | |
| *Geranium potentilloides* | HO | | c | c | | | | c | | c | o | o | | o | |
| *Pelargonium australe* | HO | | | | | | | o | o | | | o | o | | |
| GOODENIACEAE | | | | | | | | | | | | | | | |
| *Selliera radicans* | | | | | | | o | r | | | | o | | | |
| HALORAGACEAE | | | | | | | | | | | | | | | |
| *Haloragis brownii* | *1 | | | | | | o | | | | | | | | |
| *Myriophyllum salsugineum* | HO | | | | | | c | | | | | | | | |
| *Gonocarpus micranthus* subsp. *micranthus* | HO | | | | r | | | | | | | | | | |

Appendix cont.

| | Where record-ed | Status/ distri-bution | Community Types | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| LAMIACEAE | | | | | | | | | | | | | | | |
| *Mentha sp* | HO | i | | | | | | | | | | | | | o |
| *M. diemenica* | *1 | | | | | | | r | | | | | | | |
| *Ajuga australis* | HO | | | | | | | c | r | r | | | | c | |
| LAURACEAE | | | | | | | | | | | | | | | |
| *Cassytha glabella* | HO | | | | c | | | | | | | | | | |
| *Cassytha pubescens* | HO | | | c | c | | | | | | | o | | | |
| LENTIBULARIACEAE | | | | | | | | | | | | | | | |
| *Utricularia lateriflora* | HO | | | | o | c | | | | | | | | | |
| LOGANIACEAE | | | | | | | | | | | | | | | |
| *Mitrasacme pilosa* | HO | | | | r | | | r | | | | | | | |
| MENYANTHACEAE | | | | | | | | | | | | | | | |
| *Villarsia reniformis* | HO | | | | | | c | | | | | | | | |
| MIMOSACEAE | | | | | | | | | | | | | | | |
| *Acacia melanoxylon* | HO | | o | | | | | | o | o | o | | | | |
| *A. mucronata* | HO | | c | c | o | | | | c | r | | | | | |
| *A. mucronata* var. *mucronata* | HO | | | o | | | | | | | | | | | |
| *A. sophorae* | HO | | r | r | | | r | c | c | r | o | c | o | | |
| *A. suaveolens* | HO | | | r | r | | | | | | | | | | |
| *A. ulicifolia* | HO | | | r | | | | | | | | | | | |
| *A. verticillata* | HO | | c | o | | o | o | c | c | c | o | c | o | | |
| MYOPORACEAE | | | | | | | | | | | | | | | |
| *Myoporum insulare* | HO | | | r | | | r | o | o | | | c | o | | |
| MYRTACEAE | | | | | | | | | | | | | | | |
| *Eucalyptus brookeriana* | | EN | o | | | | | | | o | | | | | |
| *E. nitida* | HO | EN | c | c | o | | | | c | o | | | | | |
| *E. ovata* | HO | | o | | | | | | | o | r | | | | |
| *E. viminalis* | HO | | | | | | | | o | | | | | | |
| *Leptospermum glaucescens* | HO | EN | o | c | r | | | | c | | | | | | |
| *L. laevigatum* | HO | | c | | | | | o | | r | o | o | | | |
| *L. scoparium* | HO | | c | c | c | c | | o | c | c | c | o | | o | |
| *Melaleuca ericifolia* | HO | | c | c | | o | c | o | c | o | c | o | o | | |
| *M. squamea* | HO | | | | c | o | | | | | | | | | |
| *M. squarrosa* | HO | | c | c | c | c | | | | | | | | | |
| ONAGRACEAE | | | | | | | | | | | | | | | |
| *Epilobium sarmentaceum* | HO | | | | | | r | o | | r | | o | | o | c |
| OXALIDACEAE | | | | | | | | | | | | | | | |
| *Oxalis corniculata* subsp. *corniculata* | HO | i | c | | | | | c | | o | | o | c | c | c |
| *O. perennans* | HO | | c | | | | | | | | | | | o | |
| *O. articulata* | | i | | | | | | | | | | | | | o |
| PITTOSPORACEAE | | | | | | | | | | | | | | | |
| *Bursaria spinosa* | HO | | c | | | | | o | c | c | o | r | r | | |
| PLANTAGINACEAE | | | | | | | | | | | | | | | |
| *Plantago coronopus* | HO | i | | | | | | | | | | o | o | c | |
| *P. major* | HO | i | | | | | | | r | | | | | o | |
| POLYGONACEAE | | | | | | | | | | | | | | | |
| *Acetosella vulgaris* | | i | | | | | | c | | | | | | c | |
| *Comespermum retusum* | HO | | | | o | | | | | | | | | | |
| *C. volubile* | HO | | r | o | | | | o | o | | | | | | |
| *Muehlenbeckia adpressa* | HO | | | | | | | c | o | | | | | o | |
| PORTULACACEAE | | | | | | | | | | | | | | | |
| *Calandrinia calyptrata* | | | | | | | | | | | | o | | o | |
| PRIMULACEAE | | | | | | | | | | | | | | | |
| *Anagallis arvensis* | HO | i | | | | | | | | | | | | o | |
| *Samolus repens* | HO | | | | | | | | | | | o | | | |
| PROTEACEAE | | | | | | | | | | | | | | | |
| *Banksia marginata* | | | c | c | c | o | r | r | c | o | o | o | r | r | |
| *Persoonia juniperina* | HO | | | | o | | | | o | | | | | | |

Appendix cont.

| | Where recorded | Status/ distribution | Community Types 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RANUNCULACEAE | | | | | | | | | | | | | | | |
| *Clematis aristata* | HO | | o | | | | | | r | o | r | | | | |
| *C. microphylla* | HO | | | | | | | | o | | | | | | |
| *Ranunculus amphitrichus* | HO | | | | | | c | | | | | | | o | |
| *R. parviflorus* | HO | | | | | | | | | | | o | | | |
| *R. repens* | HO | i | | | | | | | | | | | | r | o |
| RHAMNACEAE | | | | | | | | | | | | | | | |
| *Pomaderris apetala* | HO | | o | | | | | | | | | | | | |
| ROSACEAE | | | | | | | | | | | | | | | |
| *Acaena novae-zelandiae* | HO | | | r | | | r | c | r | o | | c | c | c | |
| *A. pallida* | HO | | | | | | | o | | | | o | o | | |
| RUBIACEAE | | | | | | | | | | | | | | | |
| *Coprosma quadrifida* | | | | | | | | | | r | | | | | |
| *C. repens* | | i | | | | | | o | r | | | o | | | c |
| *Galium australe* | HO | | | | | | | | o | | o | o | | | |
| RUTACEAE | | | | | | | | | | | | | | | |
| *Boronia anemonifolia* | HO | | c | c | o | | | | c | o | o | | o | | |
| *B. parviflora* | HO | | | | r | | | | | | | | | | |
| *Correa backhousiana* | HO | | | | | | | | | | o | c | o | | |
| *Zieria arborescens* | HO | | | | | | | | | | o | | | | |
| SALICACEAE | | | | | | | | | | | | | | | |
| *Salix* sp. | HO | i | | | | | | | | | | | | | o |
| SCROPHULARIACEAE | | | | | | | | | | | | | | | |
| *Gratiola peruviana* | HO | | | | | | | | | | | r | | | |
| *Limosella australis* | HO | | | | | | c | | | | | r | | | |
| *Parentucellia latifolia* | HO | i | | | | | | o | | | | | | | |
| SOLANACEAE | | | | | | | | | | | | | | | |
| *Lycium ferocissimum* | | i | | | | | | | | | | | | | c |
| *Solanum vescum* | HO | | | | | | r | | | | r | | o | | |
| STACKHOUSIACEAE | | | | | | | | | | | | | | | |
| *Stackhousia spathulata* | HO | | | | | | | | | | | o | | | |
| THYMELAEACEAE | | | | | | | | | | | | | | | |
| *Pimelea drupacea* | HO | | r | | | | | | | | | | | | |
| *P. linifolia* | HO | | c | c | | | | o | c | c | o | | | | |
| URTICACEAE | | | | | | | | | | | | | | | |
| *Parietaria debilis* | HO | | | | | | | | | | | o | o | | |
| *Urtica incisa* | HO | | r | | | | o | o | o | | | o | c | o | |
| VIOLACEAE | | | | | | | | | | | | | | | |
| *Viola hederacea* | HO | | | o | | | | c | r | o | | | | c | |
| MONOCOTYLEDONAE | | | | | | | | | | | | | | | |
| AGAVACEAE | | | | | | | | | | | | | | | |
| *Phormium tenax* | | i | | | | | | | | | | | | | r |
| ARACEAE | | | | | | | | | | | | | | | |
| *Zantedeschia aethiopica* | | i | | | | | | | | | | | | | r |
| CENTROLEPIDACEAE | | | | | | | | | | | | | | | |
| *Centrolepis fascicularis* | HO | | | | | | | | | | | o | | | |
| *C. polygyna* | HO | | | | | | | | | | | c | | o | |
| *C. strigosa* | HO | | | | o | | r | | | | | o | | | |
| CYPERACEAE | | | | | | | | | | | | | | | |
| *Baumea acuta* | HO | | | | | | | | | | | o | | | |
| *B. arthrophylla* | HO | | | r | | | | | | | | | | | |
| *B. juncea* | HO | | | | | o | | | | | | | | | |
| *Carex appressa* | HO | | | | | | c | c | r | r | r | o | o | o | |
| *C. breviculmis* | HO | | | | | | | r | | | | r | | | |
| *Eleocharis acuta* | HO | | | | | | c | | | | | o | | | |
| *E. pusilla* | *1 | | | | | | r | | | | | | | | |
| *Gahnia grandis* | | | o | | o | c | | | | | o | | | | |
| *G. trifida* | HO | | | | | | o | | | | | | | | |
| *Isolepis fluitans* | HO | | | | | r | | | | | | | | | |

Appendix cont.

| | Where recorded | Status/ distribution | Community Types | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| *Isolepis inundata* | *1 | | | | | | c | | | | | | | | |
| *I. marginata* | HO | | | | | | c | | | | | | | | |
| *I. nodosa* | HO | | | | | | r | c | o | r | | c | c | c | |
| *Isolepis* spp. | HO | | | | | | | | | | | | o | | |
| *I. subtilissima* | HO | | | | | | o | | | | | o | | | |
| *Lepidosperma concavum* | HO | | r | | | | | | | | | | | | |
| *L. elatius* | HO | | o | | | | | | | | | | | | |
| *L. filiforme* | HO | | | | o | | | | | | | | | | |
| *L. gladiatum* | HO | | r | | | | r | o | o | | | c | | | |
| *Schoenus apogon* | | | | | | | | | | | | | | o | |
| *S. lepidosperma* | HO | | | | o | | | | | | | | | | |
| *S. nitens* | HO | | | | | | c | o | | | | o | | | |
| IRIDACEAE | | | | | | | | | | | | | | | |
| *Patersonia fragilis* | HO | | | | c | | | | | | | | | | |
| JUNCACEAE | | | | | | | | | | | | | | | |
| *Juncus caespiticius* | HO | | | | | | | | | | | o | | | |
| *J. kraussii* subsp. *australiensis* | HO | | | | | | c | | | | | o | | o | |
| *J. pallidus* | HO | | | | | | c | o | | | | r | o | o | |
| *J. pauciflorus* | HO | | | | | | c | o | | r | | | | | |
| *J. planifolius* | HO | | | | | | c | | | | | | | | |
| *Luzula densiflora* | HO | | r | | | | | | | | | r | | | |
| *L. flaccida* | HO | | r | | | | | | | r | | r | | | |
| JUNCAGINACEAE | | | | | | | | | | | | | | | |
| *Triglochin procerum* | HO | | | | | | c | | | | | | | | |
| *T. striata* | *1 | | | | | | r | | | | | | | | |
| LEMNACEAE | | | | | | | | | | | | | | | |
| *Lemna disperma* | HO | | | | | | c | | | | | r | | | |
| LILIACEAE | | | | | | | | | | | | | | | |
| *Dianella revoluta* | HO | | c | | | | | o | c | | o | o | | | |
| *D. revoluta* var. *revoluta* | HO | | | | | | | o | | | | | | | |
| *D. tasmanica* | HO | | c | | | | | | o | o | | o | o | | |
| *Drymophila cyanocarpa* | HO | | o | | | | | | | | | | | | |
| *Hyacinthoides non-scripta* | HO | i | | | | | | | | | | | | | o |
| ORCHIDACEAE | | | | | | | | | | | | | | | |
| *Burnettia cuneata* | HO | R, r3 | | | r | | | | | | | | | | |
| *Caladenia latifolia* | HO | | | | | | | | | | | o | | o | |
| *Cryptostylis subulata* | HO | | | | r | | | | | | | | | | |
| *Prasophyllum* sp. | HO | | o | | o | | | | | | | | | | |
| *Pterostylis concinna* | | | | | r | | | | | | | | | | |
| *P. cucullata* | *3 | V, r1 | | | | | | | r | | | | | | |
| *P. nana* | HO | | | | r | | | | | | | | | | |
| *P. nutans* | HO | | r | | | | | | | | | | | | |
| *P. pedunculata* | HO | | | | | | | o | | | | o | o | | |
| *P. sanguinea* | HO | r2 | | | | | | | | r | | | | | |
| *Thelymitra pauciflora* | *3 | | | r | | | | | | | | | | | |
| *Thelymitra* sp. | HO | | | | | | | | | | | o | | | |
| POACEAE | | | | | | | | | | | | | | | |
| *Aira* sp. | HO | i | | | | | | | | r | | o | o | o | |
| *Agrostis aequata* | HO | r2 | | | | | r | | | | | | | | |
| *Ammophila arenaria* | HO | i | | | | | | c | | | | c | | | |
| *Anthoxanthum odoratum* | HO | i | | | | | | | o | | | o | | o | |
| *Briza minor* | HO | i | | | | | | | | | | r | | | |
| *Bromus diandrus* | HO | i | | | | | | | r | | | o | o | o | |
| *Dactylis glomerata* | HO | i | | | | | | | | | | r | | | |
| *Ehrharta distichophylla* | | | | | | | | | | | | o | | | |
| *Glyceria maxima* | HO | i | | | | | | r | | | | | | r | |
| *Holcus lanatus* | HO | i | | c | | | o | c | o | | | c | c | c | |
| *Lolium loliaceum* | HO | i | | | | | | | | | | r | | | |
| *Poa annua* | HO | i | | | | | | | | | | r | | c | |

Appendix cont.

| | Where recorded | Status/ distribution | Community Types | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| *Poa labillardierei* | HO | | o | | | | | c | | o | | | | | |
| *P. poiformis* | HO | | o | o | | | | c | c | o | c | c | c | c | |
| *P. poiformis var ramifer* | HO | | | | | | | | | | | o | o | | |
| *Spinifex sericeus* | | | | | | | | | | | | o | | | |
| *Stipa stipoides* | | | | | | | | | | | | c | | | |
| *Vulpia bromoides* | HO | i | | | | | | | r | | | | | o | |
| RESTIONACEAE | | | | | | | | | | | | | | | |
| *Empodisma minus* | HO | | | | c | c | | | | | | | | | |
| *Lepyrodia tasmanica* | HO | | | | c | c | | | | | | | | | |
| *Restio complanatus* | HO | | | | c | | | | | | | | | | |
| *R. tetraphyllus* | HO | | | | o | c | | | | | | | | | |
| RUPPIACEAE | | | | | | | | | | | | | | | |
| *Ruppia polycarpa* | *1 | | | | | | | | | | | r | | | |
| XYRIDACEAE | | | | | | | | | | | | | | | |
| *Xyris muelleri* | HO | | | | o | | | | | | | | | | |
| GYMNOSPERMAE | | | | | | | | | | | | | | | |
| ARAUCARIACEAE | | | | | | | | | | | | | | | |
| *Araucaria heterophylla* | HO | i | | | | | | | | | | | | | r |
| CUPPRESSACEAE | | | | | | | | | | | | | | | |
| *Cupressus macrocarpus* | HO | i | | | | | | | | | | | | | o |
| PINACEAE | | | | | | | | | | | | | | | |
| *Pinus radiata* | | i | | | | | | | | | | | | | o |
| PTERIDOPHYTA | | | | | | | | | | | | | | | |
| ASPLENIACEAE | | | | | | | | | | | | | | | |
| *Asplenium obtusatum* | HO | | | | | | | | | | | c | | | |
| AZOLLACEAE | | | | | | | | | | | | | | | |
| *Azolla filiculoides* | HO | | | | | | o | | | | | | | | |
| BLECHNACEAE | | | | | | | | | | | | | | | |
| *Blechnum wattsii* | HO | | o | | | | | | | | | | | | |
| DENNSTAEDTIACEAE | | | | | | | | | | | | | | | |
| *Histiopteris incisa* | HO | | o | | | | | | | o | c | | | | |
| *Pteridium esculentum* | HO | | c | c | | | | c | c | c | c | o | c | c | |
| *Hypolepis rugosula* | HO | | o | | | | | | | o | | | | | |
| *Hypolepis* sp. | HO | | r | | | | | | | | | | | | |
| DICKSONIACEAE | | | | | | | | | | | | | | | |
| *Dicksonia antarctica* | HO | | r | | | | | | | r | | | | | |
| DRYOPTERIDACEAE | | | | | | | | | | | | | | | |
| *Rumohra adiantiformis* | HO | | | | | | | | | | | r | | | |
| GLEICHENIACEAE | | | | | | | | | | | | | | | |
| *Gleichenia microphylla* | HO | | o | r | | c | | | | | | | | | |
| GRAMMITIDACEAE | | | | | | | | | | | | | | | |
| *Grammitis* sp. | HO | | r | | | | | | | | | | | | |
| POLYPODIACEAE | | | | | | | | | | | | | | | |
| *Phymatosorus pustulatus* | HO | | r | | | | | | r | r | | r | | | |
| PTERIDACEAE | | | | | | | | | | | | | | | |
| *Pteris tremula* | HO | | r | | | | | | | | | | | | |
| SCHIZAEACEAE | | | | | | | | | | | | | | | |
| *Schizaea fistulosa* | HO | | | | o | c | | | | | | | | | |
| SELAGINELLACEAE | | | | | | | | | | | | | | | |
| *Selaginella uliginosa* | HO | | | | c | | | | | | | | | | |

# THE FLORA OF TOWNSHIP LAGOON NATURE RESERVE AND ITS MANAGEMENT, TUNBRIDGE, TASMANIA

by Andrew Zacharek, L. Gilfedder and S. Harris

(with four tables, four text-figures, two plates and an appendix)

ZACHAREK, A.R., GILFEDDER, L. & HARRIS, S., 1997 (31:viii): The flora of Township Lagoon Nature Reserve and its management, Tunbridge, Tasmania. *Pap. Proc. R. Soc. Tasm.* 131: 57–66. ISSN 0800-4703. Department of Geography and Environmental Studies, University of Tasmania, GPO Box 252-78, Hobart 7001 (AZ); Parks and Wildlife Service, Department of Environment and Land Management, GPO Box A, Hobart 7001 (SH, LG), formerly Department of Geography and Environmental Studies (LG).

Township Lagoon Nature Reserve is 16 ha of remnant native grassland in the lowest rainfall area of Tasmania. A high proportion of rare and threatened species occurs within the reserve. They comprise four endangered species, including three endangered at the national level, four vulnerable species and eight rare species, seven of the above being daisies. There is a strong floristic affinity with the semi-arid mallee ground flora in northwestern Victoria and western New South Wales. The small grassland remnant comprises five floristic communities, the principal influences on floristic variation being exerted by soil factors, such as geology, pH and drainage, and past history of mechanical disturbance and rubbish dumping. Active conservation management, that is favourable to the continued existence of vulnerable and rare species, promotes normal ecosystem functions and prevents threatening processes, is essential.

**Key Words: vegetation, nature reserve, salt lake, weeds, rare and threatened plants, low rainfall flora, Tasmania.**

## INTRODUCTION

Township Lagoon Nature Reserve at Tunbridge in the southern Tasmanian Midlands, is a native grassland and grassy woodland remnant dominated mainly by kangaroo grass *(Themeda triandra).* An early painting of the Salt Pan Plains by Joseph Lycett indicates that the pre-European vegetation of the area was a treeless grassy plain (Fensham 1989). Township Lagoon Nature Reserve is listed on the Register of the National Estate and also protects one of only four natural salt lakes that occur in Tasmania. Natural grasslands and grassy woodlands were once extensive in the lowlands of the Midlands, but today the natural vegetation has been dramatically altered, with only 13% of the vegetation resembling the original remaining and virtually all of this privately owned (e.g. Fensham & Kirkpatrick 1989, Gilfedder & Kirkpatrick 1995b). The Midlands were arguably the birthplace of the agricultural and pastoral industries in Australia. In Tasmania, grasslands and grassy woodlands are the most threatened vegetation type, with 22 of the 37 communities described for Tasmania being unprotected in any national park or state reserve (Kirkpatrick *et al.* 1988). There is a high concentration of rare and threatened plant taxa in the Midlands (Kirkpatrick *et al.* 1988, Gilfedder 1990), including many species that are not protected in any other state reserve (Kirkpatrick *et al.* 1991a, b). The reserve has been recognised as an important grassland remnant (Kirkpatrick *et al.* 1988; Kirkpatrick *et al.* 1991a). It is an important locality for the glossy tussock lizard *Pseudemoia pagenstecheri* (Rounsevell *et al.* 1996), the isopod, *Haloniscus searlei* (Fulton 1976) and a recently rediscovered moth *(Chrysolarentia decisaria)* and rare grasshopper *(Brachyxema lobipennis)* (P. McQuillan, pers. comm.). The area is an important faunal refuge for rare invertebrates. Two crustaceans recorded from saline waters on mainland Australia have their only known Tasmanian occurrences at Township Lagoon (Fulton 1976). They are the isopod *Haloniscus searlei* Chilton and the ostracod *Australocypris robusta* De Deckker. The water fleas *Diacypris* sp. nova and *Calamoecia clitellata* Bayly also occur at Township Lagoon (Buckney & Tyler 1976).

The aims of this study are to produce an inventory of the flora, to describe the vegetation communities, to gain understanding of the environmental factors, including the role of fire, and to make preliminary recommendations on management of the reserve.

## MATERIALS AND METHODS

### The Study Area

Township Lagoon Nature Reserve (fig. 1; pls 1, 2)is an area of approximately 16 ha which was set aside for the expansion of the town of Tunbridge and remained unallocated crown land until the mid-1980s, when its conservation significance was recognised. The area was proclaimed as a Nature Reserve on 25 December 1991.

The climate of the Tunbridge district is dry subhumid cool (Gentilli 1972), characterised by a long warm season and peak rainfall in the spring and autumn. This is one of the lowest rainfall areas in the state, with a mean annual rainfall of 462 mm per annum (table 1). The mean daily minimum temperature for the coldest month is 1.1°C; the mean daily maximum temperature for the warmest month is 22.6°C (table 1). Annual rainfall for 1990–92 and 1994–96 has been, on average, 430 mm, which is 93% of the long-term average, indicating the unreliability of rainfall (fig. 2).

The reserve is underlain by Tertiary basalt in the elevated areas of the reserve. The basalt overlies Triassic sediments which crop out in the lower areas around and to the east of the lagoon. The site is at approximately 200–240 m elevation. The soils consist of clay and very dark-brown to black, duplex clay loam, and are fertile, with moderate to high permeability (Davies 1988).

The reserve was leased for stock-grazing until the 1960s and is at present irregularly and lightly grazed. Patches of

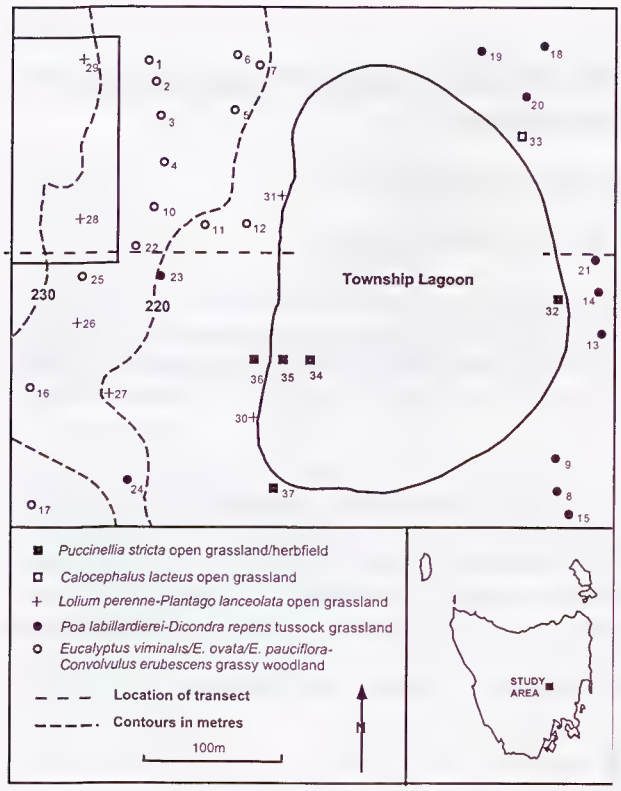


*FIG. 1 — Township Lagoon Nature Reserve at Tunbridge in the Midlands of Tasmania (42°8'S, 147°15'E).*

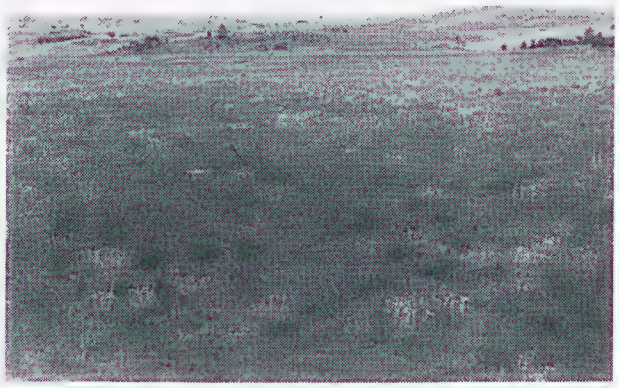

*PLATE 1*
*View looking south with* Themeda triandra *grassland with abundant flowering heads of* Chrysocephalum apiculatum *at Township Lagoon Nature Reserve, Tunbridge (Dec. 1991). Photo: A. Zacharek.*

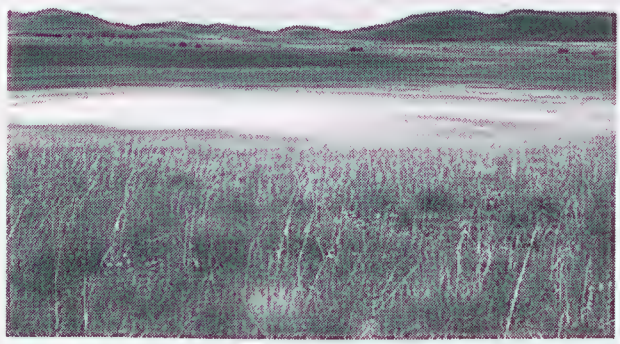

*PLATE 2*
*Looking east toward Township Lagoon across* Themeda triandra *grassland (Dec. 1991). Photo: A. Zacharek.*

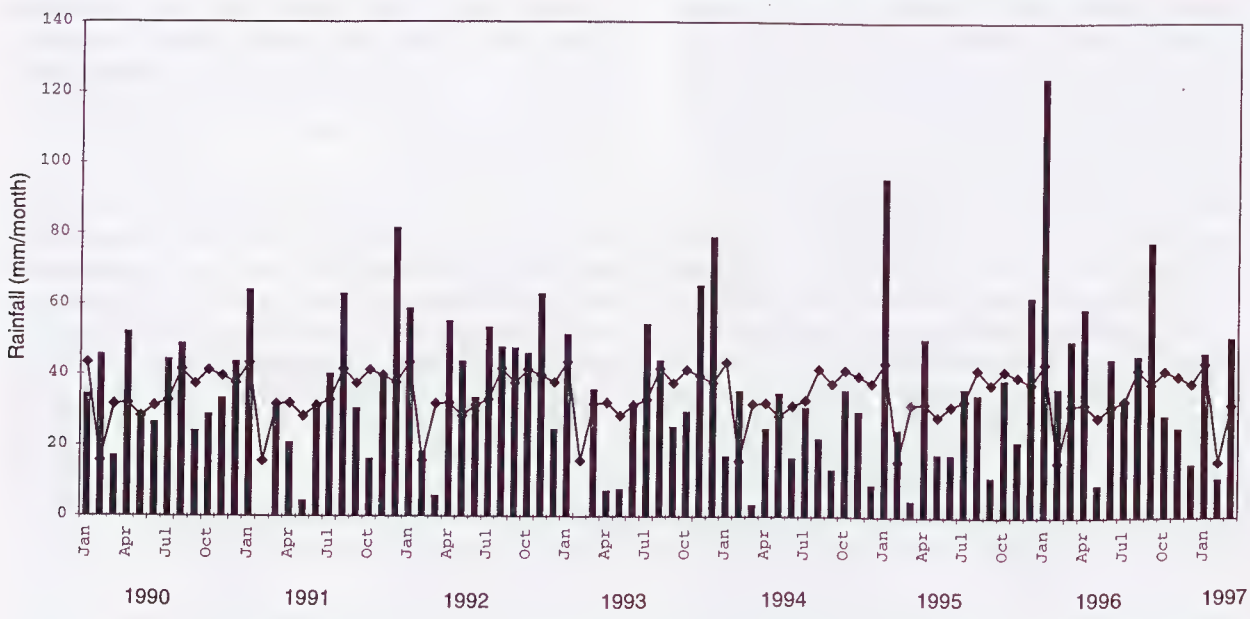


*FIG. 2 — Mean monthly rainfall at Tunbridge, 1990–March 1997; the long-term monthly average is calculated from Bureau of Meteorology data covering the period 1972–97. Annual precipitation totals were 443mm (1990), 421 mm (1991), 494 mm (1992), 270 mm (1994), 413 mm (1995) and 545 mm (1996); the 1993 data is incomplete. Monthly precipitation is indicated by bars and the line indicates the long-term monthly average.*

TABLE 1
**Summary of precipitation and rain days for Tunbridge* and temperature data for Ross†**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tunbridge* total monthly precipitation** | | | | | | | | | | | | | |
| Mean | 43.3 | 19.5 | 33.4 | 39.3 | 37.2 | 32.9 | 41.0 | 40.7 | 39.3 | 40.8 | 44.2 | 44.4 | 461.5 |
| Highest | 124 | 62.0 | 75.2 | 94.6 | 92.0 | 76.0 | 103.6 | 83.8 | 116.6 | 73.6 | 110.8 | 140.2 | 633.5 |
| Lowest | 4.8 | 0.0 | 3.2 | 5.6 | 4.2 | 11.2 | 11.4 | 3.8 | 9.6 | 13.0 | 7.6 | 6.0 | 269.6 |
| Number | 24 | 23 | 24 | 23 | 23 | 24 | 24 | 24 | 25 | 25 | 25 | 25 | 22 |
| **Tunbridge * raindays** | | | | | | | | | | | | | |
| Mean | 7.8 | 5.0 | 7.5 | 9.5 | 10.4 | 11.5 | 12.9 | 13.0 | 11.5 | 10.9 | 10.3 | 9.3 | 119.8 |
| Highest | 12 | 11 | 12 | 17 | 16 | 14 | 20 | 20 | 19 | 22 | 16 | 23 | 138 |
| Lowest | 4 | 0 | 2 | 4 | 5 | 8 | 7 | 3 | 2 | 5 | 4 | 2 | 95 |
| Number | 24 | 23 | 24 | 23 | 23 | 24 | 24 | 24 | 25 | 25 | 24 | 25 | 22 |
| **Ross†, summary of daily temperature** | | | | | | | | | | | | | |
| Mean daily max. temp. | 22.6 | 22.1 | 20.3 | 16.1 | 13.7 | 10.9 | 10.5 | 11.9 | 13.0 | 16.7 | 18.2 | 21.7 | 16.5 |
| Highest temp. | 34.6 | 34.0 | 28.8 | 23.2 | 18.7 | 15.8 | 15.7 | 18.0 | 19.7 | 28.8 | 26.6 | 33.9 | 34.6 |
| Lowest Max. temp. | 14.4 | 13.1 | 12.6 | 9.9 | 8.7 | 5.7 | 4.3 | 7.9 | 7.7 | 10.1 | 10.4 | 13.4 | 4.3 |
| Mean daily min. temp. | 10.2 | 10.1 | 7.1 | 5.6 | 2.7 | 1.5 | 1.1 | 2.3 | 2.5 | 4.9 | 6.1 | 8.0 | 5.2 |
| Highest min temp. | 18.9 | 18.9 | 14.8 | 15.8 | 12.1 | 12.5 | 9.6 | 10.0 | 10.2 | 12.4 | 12.9 | 17.2 | 18.9 |
| Lowest temp. | 0.5 | 1.5 | −1.6 | −4.3 | −5.9 | −6.6 | −6.2 | −5.8 | −4.2 | −3.2 | −1.5 | −2.5 | −6.6 |

* Cheam (42°07'S, 147°21'E), elevation 220 m; available data 1972–97.
† 42°02'S, 147°30'E, elevation 195 m; data 1993–97.

native grassland and grassy woodland in paddocks adjacent and to the west, south and north of the reserve are contiguous with the grasslands of the nature reserve. In particular, on a hill on adjacent private land to the west of the reserve, grassy woodland dominated by *Eucalyptus pauciflora* occurs. Approximately half of the land adjacent to the reserve has been sown to improved pastures or crops.

In the northwestern corner of the block an area of 1 ha is fenced off and currently used as a refuse disposal site but, in the past, more extensive areas were used, and sporadic rubbish dumping in the reserve still occasionally occurs. In addition, along the edges of the block, public rights of way exist, and these are used for access to adjacent land. Driving of vehicles on the native vegetation and on the dry lagoon bed is common.

The reserve is irregularly burned, when fires escape from the rubbish tip. In 1987, a fire burnt most of the area to the west of the lagoon. In December 1993, patches of the grassy vegetation to the west of the lake were subject to a planned burn but, in September 1994, a large proportion of the remaining area was burned by a fire of unknown origin.

## Vegetation Sampling

Thirty-seven quadrats were located in a subjective without preconceived bias manner (Mueller-Dombois & Ellenberg 1974) in the reserve. Each quadrat measured 10 x 1 m, and all vascular plant species were recorded, both in November 1991 and in January 1992, to maximise the chances of positive identification of species. Authorities for species nomenclature follow Buchanan (1995). Slope and aspect were recorded, using a clinometer and a compass respectively. Soil pH was determined for each quadrat, using a CSIRO soil-testing kit.

The polythetic divisive classification program TWINSPAN (Hill 1979) was used to help sort the 10 x 1 m quadrat data into floristic groups, using the presence of native species only. With the 10 x 1 m quadrats, two groups were separated on the second division of TWINSPAN, one on the third, and two on the fourth levels. Four quadrats were manually reassigned. The frequencies of species in the quadrats of the floristic groups were calculated. The floristic groups that corresponded most closely to the plant communities of Kirkpatrick *et al.* (1988) were determined.

A transect line, running orthogonal to the slope (fig. 1.), was placed across the nature reserve and into the adjacent native pasture on private land, and was surveyed, using a tape and dumpy-level. Forty-four 1 x 1 m quadrats were located along the transect, at 10 m intervals, with an estimate of the percentage cover of all higher plant species, the combined cover for native and exotic grasses and forbs, and bare ground (Mueller-Dombois & Ellenberg 1974). Native, exotic and total plant species richness per plot were determined.

Soil samples from the transect were weighed after air-drying overnight. The samples were then dried in an oven at 105°C for 30 min. to determine soil moisture (Rayment & Higginson 1992). Organic matter was then estimated as loss on ignition by heating the soil samples at 550°C for one hour.

## Burning Experiment

The effects of an unplanned fire on the *Themeda triandra* tussock grassland at Township Lagoon were monitored for 27 months to determine how quickly the above-ground

biomass recovered, and to monitor any short-term changes in the species composition of the area. Twenty 0.25 x 0.25 m quadrats were randomly located over the area at each harvest and the above-ground biomass was removed (biomass in this context is taken as the net primary aerial production of the grassland) and sorted into component parts. Dry weight was determined following oven drying at 105°C for 24 hours. The biomass was harvested at regular intervals to coincide approximately with the peak of the growing season and the end of the growing season. The study area was burned in mid-October 1986, and harvests were made at three weeks (6 November 1986), 8.5 weeks (17 December 1986), 13 weeks (17 January 1987), 55 weeks (10 November 1987), 69 weeks (20 February 1988) and 117 weeks (24 January 1989). Floristic data were available for the study area prior to the fire, and quadrat data were collected post-fire, so that comparisons were possible.

## RESULTS

The reserve has a high plant community diversity, ranging from a distinct assemblage of saltmarsh species on the shores of the saltlake, *Poa* tussock grassland to *Themeda triandra* grassland and grassy woodland, and is also an area of high native plant species richness, considering its small area (16 ha). The 114 native species found in Township Lagoon Nature Reserve represent approximately 15% of the 750 native plant species of grasslands in Tasmania (Kirkpatrick 1994), while the 75 exotic species present comprise 14% of the total exotic species in Tasmania (table 2). There is a very high concentration of endangered, vulnerable and rare species, as listed in Schedules 3 to 5 of the *Threatened Species Protection Act* 1995 (Tasmania). There are four endangered, four vulnerable and eight rare species, and of the four endangered species, three are endangered nationally (table 3). The full list of species found in the reserve is given in appendix 1.

### Plant communities

The vegetation is best represented by five floristic groups; these are listed below, with plant species that were found in at least 40% of the quadrats. In some cases, species which were characteristic of a community but were sporadic in occurrence are included. The soil types and pH and species richness for the floristic groups are listed in table 4.

The floristic groups are as follows (numbers of quadrats in the groups in parentheses):

**Floristic Group 1** *Puccinellia stricta* open grassland/herbfield (n=5)
Native graminoids: *Puccinellia stricta*
Native forbs: *Apium prostratum, Spergularia media, Isolepis* sp., *Selliera radicans*
Exotic graminoids: *Hordeum marinum*
Exotic forbs: *Plantago coronopus, Leontodon taraxacoides*

The vegetation comprises very prostrate, succulent species and exotic rosette herbs near the lake edge, with other species away from the lake in areas of low relief that may be affected by winds blowing across the lake. There was a high percentage of bare ground, and the soils have heavy black clay A horizons (pH 9) over brown clay B horizons that overlay sandstone.

TABLE 2
**Number of plant species and categories recorded at Tunbridge Township Lagoon Nature Reserve**

| Category* | Number | % of total |
|---|---|---|
| Total species | 189 | 100 |
| Native species | 114 | 60 |
| Introduced species | 75 | 40 |
| Endemic species | 6 | 3.2 |
| Endangered | 4 | 2.1 |
| Vulnerable | 4 | 2.1 |
| Rare | 8 | 4.2 |
| Dicotyledons | 126 | 67 |
| Monocotyledons | 62 | 33 |
| Ferns | 1 | <1 |

* Conservation status is according to Schedules 3 to 5 of the *Threatened Species Protection Act* 1995 (Tasmania).

TABLE 3
**List of vascular plant species endangered, vulnerable or rare in Tasmania***

**Taxa of flora which are endangered**
ASTERACEAE
*Leucochrysum albicans* (A. Cunn.) Paul G. Wilson subsp. *albicans* var. *tricolor* (DC.) Paul G. Wilson (Hoary Sunray) (E)
BRASSICACEAE
*Lepidium hyssopifolium* Desv. (Peppercress) (E)
RANUNCULACEAE
*Ranunculus prasinus* Menadue (Tunbridge Buttercup) (E, EN)
STACKHOUSIACEAE
*Stackhousia gunnii* Hook.f. (Gunn's Mignonette) (EN)

**Taxa of flora which are vulnerable**
ASTERACEAE
*Brachyscome rigidula* (DC.) G.Davis (Hairy Cutleaf Daisy)
CARYOPHYLLACEAE
*Scleranthus diander* R.Br. (Knawel)
FABACEAE
*Pultenaea prostrata* Benth. ex Hook.f. (Bush Pea)
GOODENIACEAE
*Velleia paradoxa* R.Br. (Spur Velleia)

**Taxa of flora which are rare**
ASTERACEAE
*Calocephalus lacteus* Less. (Milky Beauty-heads)
*Craspedia* sp. (Tunbridge) (Billy Buttons)
*Vittadinia cuneata* DC. (New Holland daisy)
*V. gracilis* (Hook.f.) N.Burb. (New Holland daisy)
*V. muelleri* N.Burb. (Narrow-leaf New Holland daisy)
CONVOLVULACEAE
*Wilsonia rotundifolia* Hook. (Round-leaf Wilsonia)
POACEAE
*Agrostis aemula* R.Br. var. *aemula* (Blown Grass)
*Stipa nodosa* S.T. Blake (Spear Grass)

* According to Schedules 3 to 5 of the *Threatened Species Protection Act* 1995 (Tasmania). E = nationally endangered species, EN = endemic to Tasmania (Flora Advisory Committee 1994).

TABLE 4
**Summary of principal influences and species richness for the five floristic groups***

| Group | Geology | A horizon | pH† | Slope† | Aspect | Native species richness† | Exotic species richness† |
|---|---|---|---|---|---|---|---|
| 1 | Sandstone | Heavy black clay | 9.5 | 0.5 | N–E | 3.8 ± 1.3 | 3.2 ± 2.7 |
| 2 | Sandstone | Heavy black clay | 9.5 | Flat | | 5.0 | 6.0 |
| 3 | Dolerite | Medium brown clay | 6.1 | 2.3 | N–E | 6.2 ± 4.8 | 14.0 ± 4.2 |
| 4 | Sandstone | Heavy black clay | 6.9 | 1.7 | S–E | 17.5 ± 3.1 | 6.6 ± 1.8 |
| 5 | Dolerite | Medium brown clay | 6.7 | 5.5 | N–E–S | 19.6 ± 4.5 | 6.9 ± 4.4 |

* Determined using TWINSPAN.
† Mean and standard deviation.

**Floristic Group 2** *Calocephalus lacteus* open grassland (n=1)
Native grasses: *Danthonia tenuior, Puccinellia stricta*
Native forbs: *Calocephalus lacteus, Selliera radicans, Asperula conferta*
Exotic grasses: *Hordeum marinum, Lolium perenne*
Exotic forbs: *Leontodon taraxacoides, Plantago coronopus, Trifolium dubium, Scorznera laciniata*

The vegetation in this quadrat represents a distinct floristic group and is located near the lake edge. It consists of *Calocephalus lacteus* interspersed with patches dominated by *Danthonia tenuior* with a range of exotic and native grass and forb species. The soil consists of a black cracking clay A horizon (pH 9), over brown clay B horizon overlying sandstone, and the ground is flat.

**Floristic group 3** *Lolium perenne–Plantago lanceolata* open grassland (n=6)
Native grasses: *Danthonia tenuior, Stipa nodosa*
Native forbs: *Asperula conferta* var. *conferta*
Exotic grasses: *Lolium perenne, Bromus hordeaceus, Bromus diandrus, Cynosurus echinatus, Poa bulbosa*
Exotic forbs: *Plantago lanceolata, Cirsium vulgare, Tragopogon porrifolius, Trifolium dubium, Hypochoeris radicata*

Quadrats in this group are from areas that had been mechanically disturbed or had been subject to refuse dumping. The vegetation is a dense sward, dominated by *Lolium perenne* and the annual exotic grasses *Bromus hordeaceus, B. diandrus* and *Cynosurus echinatus*, with native grasses and exotic forbs subdominant. Soils are dark-brown clay loam A horizons with evidence of rubbish dumping or mechanical disturbance over dark-brown to black medium clay B horizons. Slopes are less than 3° and aspects are north to northeast. The vegetation is variable and appears to be related to the type of disturbance and time since last disturbance.

**Floristic group 4** *Poa labillardierei–Dichondra repens* tussock grassland (n=11)
Native grasses: *Poa labillardierei, Themeda triandra, Danthonia tenuior, Elymus scaber*
Native forbs: *Dichondra repens, Plantago varia, Pimelea humilis, Asperula conferta* var. *conferta, Geranium solanderi, Vittadinia muelleri, Acaena echinata, Convolvulus erubescens*
Exotic grasses: *Cynosurus echinatus*
Exotic forbs: *Plantago lanceolata, Hypochoeris radicata, Centaurium erythraea*

The vegetation in this group is dominated by *Poa labillardierei* with *Themeda triandra* as a subdominant. In areas subject to regular trampling and compaction by sheep and vehicles, *Danthonia tenuior* is dominant. A large diversity of native and exotic intertussock forbs and graminoids exist. This group is found to the east and at low height above the lake on soils with heavy black clay A horizons over brown clay B horizons which overlay sandstone. In contrast to floristic groups 1 and 2, pH is near neutral. Slopes are less than 3° and aspects are variable. This is community *Poa labillardierei–Dichondra repens* tussock grassland (Pld) of Kirkpatrick *et al.* (1988).

**Floristic group 5** *Eucalyptus viminalis/E. ovata/E. pauciflora–Convolvulus erubescens* grassy woodland (n=14)
Native grasses and graminoids: *Themeda triandra, Schoenus absconditus, Danthonia tenuior, Poa rodwayi*
Native forbs: *Geranium solanderi, Chrysocephalum apiculatum, Pimelea humilis, Oxalis perennans, Scleranthus diander, Plantago varia, Asperula conferta* var. *conferta*
Exotic grasses: *Aira caryophyllea, Poa bulbosa*
Exotic forbs: *Centaurium erythraea, Hypochoeris radicata*

This plant community is widespread in the nature reserve and adjacent native pastures. It is dominated by *Themeda triandra*, with a large diversity of other native species in the intertussock spaces. *Poa rodwayi* is subdominant. *E. pauciflora* is present in the adjacent woodland on private land but is absent from the nature reserve. As with floristic group 3, the soils of quadrats in this group have dark-brown clay loam A horizons over dark-brown to black medium clay B horizons, but evidence of mechanical disturbance is absent. This floristic group is not found on sandstone. The slopes are 0° to 100° and the aspects north to east. This community corresponds to *Eucalyptus viminalis/E. ovata/E. pauciflora–Convolvulus erubescens* grassy woodland (Evc) of Kirkpatrick *et al.* (1988).

Exotic species richness is high, both at low elevation near the lake and in areas where rubbish dumping has occurred. At low elevation, exotic species richness is associated with high soil moisture and bare ground, and exotic species include *Hordeum murinum, Plantago coronopus* and *Poa bulbosa* (fig. 3). Areas of past rubbish-dumping and mechanical disturbance are associated with low bare ground and low native species richness. Abundant exotic species include *Plantago lanceolata, Poa bulbosa* and *Cynosurus echinatus* (fig. 3). *Hypochoeris radicata, Aira caryophylla* and *Briza minor* are ubiquitous in the reserve.

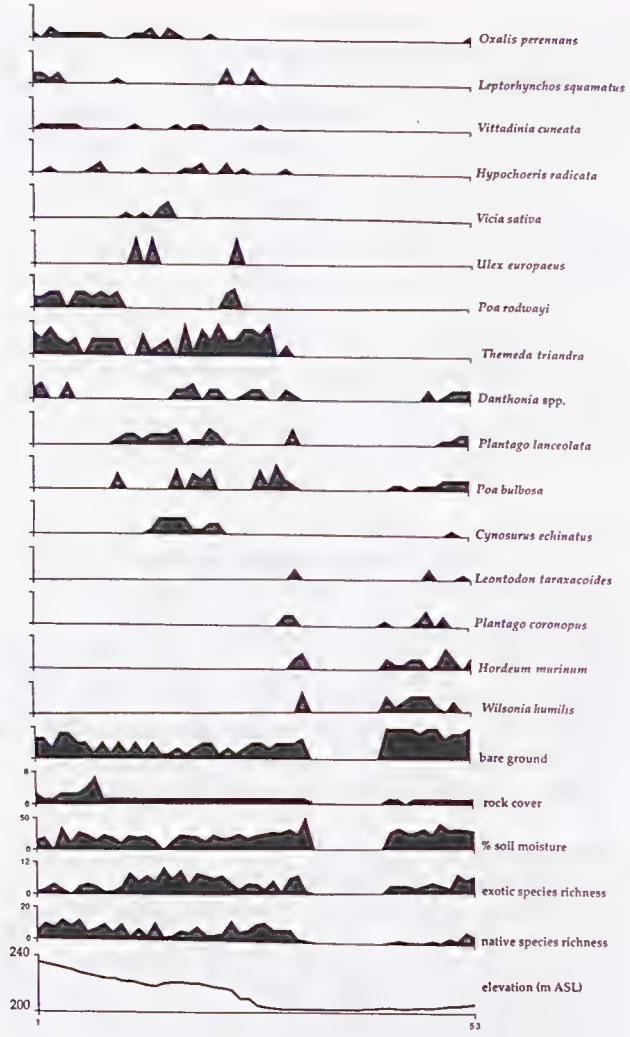


*FIG. 3 — Braun-Blanquet cover of plant species in more than 40% of the quadrats (Mueller-Dombois & Ellenberg 1974), percentage cover of bare ground and rock, percentage soil moisture, exotic and native species richness, and the elevation recorded along a transect at Township Lagoon Nature reserve.*

## Recovery Following Fire

The recovery from fire by *Themeda triandra* tussock grassland at Tunbridge, following a spring burn, was rapid. Vegetation recovery following fire was rapid, with fuel loads reaching 5 tonnes/ha after one year, the majority of which was *T. triandra* (fig. 4). *T. triandra* always dominated the biomass, ranging from 63% to 91%. There was little change in the floristic composition of the study site pre- and post-fire. Only two species, the orchid *Pterostylis commutata* and the daisy *Leucochrysum albicans* var. *tricolor*, were seen post-fire that had not been previously recorded. The percentage cover of most species post-fire remained at similar levels to pre-fire, with the dominant perennial grass *T. triandra* resuming 75–100% cover immediately post-fire. The relationship between shoot biomass and time in *Themeda* grassland has been shown to be curvilinear, with the rate of biomass increase reaching almost zero by five years (Groves 1974). This research supports other findings indicating that a fire interval of 2–3 years is most appropriate for this vegetation type for fuel reduction (McDougall 1989).

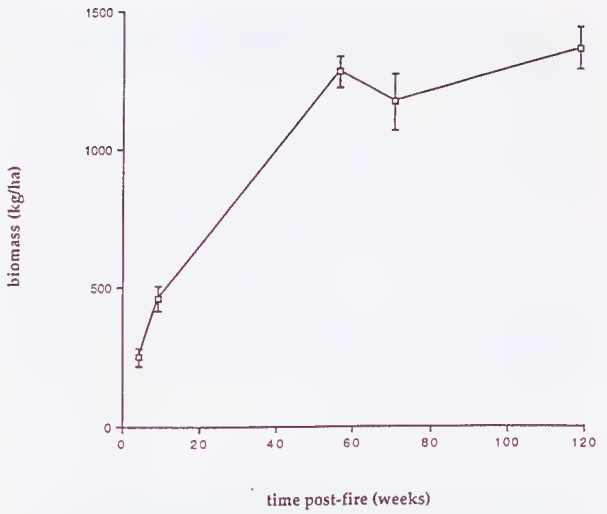


*FIG. 4 — Rate of growth of* Themeda triandra *following fire. Mean and standard error of biomass is shown.*

## DISCUSSION

The diverse vegetation of the reserve can be explained by environmental factors including geology and soils, pH and drainage, and by the broad-scale and localised history of mechanical disturbance and rubbish dumping. The importance of the reserve for endangered, vulnerable and rare species, the abundance of exotic species, and the current uses of the reserve by the local community require consideration in management. Active conservation management is essential to maintaining the condition of the reserve. It needs to be favourable to the continued existence of the threatened species, while promoting normal ecosystem processes and preventing threatening processes from taking place.

Creation of a mosaic of different ages by doing small patch burns is desirable, when the overall area of vegetation is small (<10 ha). These need to be undertaken at different times of the year. The escape of fires from the refuse site, however, is impossible to predict. The biomass of *Themeda* recovers quickly following fire, with the greatest rate of shoot growth occurring within 12 months of the fire. It is an effective form of biomass reduction. It is important that some areas are left unburned, if possible. One patch that has not been burned for at least a decade is currently the focus of soil seed bank and invertebrate studies. The area has traditionally been used as a "common" area for sheep grazing, and there is no indication that occasional light grazing is detrimental to the grassland.

Weed invasion, especially by gorse *(Ulex europaeus)*, is one of the processes which most seriously threatens the long-term viability of this small reserve. In the old tip site, research has shown that weeding techniques, such as topsoil stripping, application of herbicides and burning, can reduce exotic species and favour native species, if used with an understanding of the ecology of the species (Zacharek 1997). Restoration of native vegetation in the larger areas of exotic invasion requires more research. Vehicle access continues to be a problem, with recreational use of the dried-up bed of the salt lake. Access to the grassy areas is leading to soil compaction and subsequent weed invasion.

A conservation introduction of the Tunbridge buttercup *Ranunculus prasinus,* to the nature reserve has been successfully completed (Gilfedder *et al.* 1997, and the site is suitable for other grassland introductions of rare and threatened species, subject to appropriate guidelines (ANPC 1997). The re-introduction of the weeping dryland form of cabbage gum *(Eucalyptus pauciflora)* is also a management option. It does not currently occur in the reserve, but is in adjacent paddocks, where sheep-grazing has reduced the competition from grasses and allowed the establishment of seedlings.

## Rare and Threatened Species

The reserve is important for the conservation of rare and threatened flora and fauna. Six endangered species, including four endangered at the national level, two vulnerable species, and eight rare species were recorded, six of which were daisies. Management needs to be primarily concerned with the maintenance of these species.

The rubble peppercress *(Lepidium hyssopifolium),* once extending in its distribution from the South Australian border to northern New South Wales, is now endangered throughout its range in southeastern Australia. It is a member of the Brassicaceae family and was thought to be extinct on the Australian mainland (Leigh *et al.* 1984) until the mid-1980s, when six small populations were located in Victoria (Cropper 1987). By 1990, only two populations remained in Victoria (Scarlett & Parsons 1991). In Tasmania, only one population was known by 1990, and a previously recorded population (Leigh *et al.* 1984) had disappeared. Thirty extant populations have been located in the past five years (Gilfedder & Kirkpatrick 1995a), and the Tunbridge population, represented by only a handful of individuals, represents the only population protected in a secure reserve in Tasmania. It is a perennial species that requires soil disturbance for its regeneration, and it occurs in an area that was previously allocated for refuse disposal. Soil disturbance in this area would lead to an enhancement of the population numbers and would be a practical management option.

The straw daisy, *Leucochrysum albicans* var. *tricolor,* also a nationally endangered grassland species, occurs in northwestern Tasmania and the Midlands (Gilfedder & Kirkpatrick 1994). The population at Tunbridge, which numbers less than 30 individuals, is the only lowland population that is not on private land. Thousands of individuals occur on nearby grazing land and their future is secure at these sites if the current land use continues, for grazing by sheep reduces the competition from the grasses and favours this unpalatable daisy.

The Tunbridge buttercup, *Ranunculus prasinus,* is an endemic species first collected in 1983 (Menadue & Crowden 1985). It has a very restricted distribution, limited to four sites in the low rainfall area in the central Midlands. It does not naturally occur at this locality, but was introduced to the edges of the lagoon from three populations within a 10 km radius of the reserve (Gilfedder *et al.* 1997). The aim was to secure a population within a conservation reserve, although the current management at all four wild populations is favourable to its continued existence at these sites. The Tunbridge area is currently a declared drought area, and the fate of the introduced plants is unsure.

Two species await taxonomic studies to determine their status, but both have previously been considered at risk. These are *Stackhousia gunnii,* which, until recently, was thought to be a Tasmanian grasslands endemic (Curtis & Morris 1975), but is now one of 13–14 taxa that have been subsumed in a taxonomic revision (Barker 1984) into *S. monogyna.* In Tasmania, *S. gunnii,* is highly distinct from *S. monogyna* and is considered an endangered taxon (Gilfedder & Kirkpatrick 1997). An undescribed species, *Craspedia* species (Tunbridge), which is thought to be endemic to Tasmania and occurs on basalt soils in low rainfall areas in the central Midlands and the Bothwell district, also occurs at the Township Lagoon Nature Reserve.

The Tunbridge district is in an area where mean annual evaporation equals or exceeds rainfall, resulting in the formation of salt lakes. Township Lagoon is the only closed saline lake on crown land in Tasmania, occurring in one of two small areas of endorheic (permanently saline) lagoons in Tasmania (Tunbridge and northwest of Ross) (Buckney & Tyler 1976). The floor of the lake is a soft layer of mud overlain by a hard crust of salt, and salt has traditionally been harvested from the shores of this lagoon, and others in the district.

Lowland temperate grasslands are important for the conservation of rare and threatened lizard species in southeastern Australia (Osborne *et al.* 1995). The recently described glossy tussock skink *(Pseudemoia pagenstecheri)* occurs in dense *Themeda triandra* grasslands in the nature reserve. This is one of only a few known locations and the only reserved one (Rounsevell *et al.* 1996). A moth, previously presumed to be extinct in Tasmania, *Chrysolarentia decisaria* (Walker), was rediscovered at Township Lagoon. Its last collection was in 1904, and its status in Victoria is uncertain (P. McQuillan, pers. comm.). Also, a rare grasshopper *(Brachyxema lobipennis)* has been recorded recently at Township Lagoon Nature Reserve (P. McQuillan, pers. comm.). These species are listed by the Invertebrate Advisory Committee (1994).

In summary, the proclamation of the Township Lagoon Nature Reserve has been an important step in grassland conservation in Tasmania It is a site of high botanical and faunal significance, and an important remnant and refuge in an area which is largely improved pasture and crops. Periodic inspection by Parks and Wildlife Service field staff, the involvement of the local community, and the preparation of a management plan which includes prescriptions for the perpetuation of the existing native biota will all be important requirements for the reserve.

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## APPENDIX 1

**List of vascular plants recorded at Township Lagoon Nature Reserve.**

Species nomenclature follows Buchanan (1995).

(I) following species name = introduced taxa; (E) = taxa endemic to Tasmania.

DICOTYLEDONS

AMARANTHACEAE
- *Ptilotus spathulatus* (Pussy Tails)

APIACEAE
- *Apium prostratum* (Sea Celery)
- *Daucus glochidiatus* (Austral Carrot)
- *Lilaeopsis polyantha* (Creeping Crantzia)
- *Trachymene humilis*

ASTERACEAE
- *Bellis perennis* (English Daisy) (I)
- *Brachyscome aculeata* (Field Daisy)
- *B. rigidula* (Hairy Cutleaf Daisy)
- *Calocephalus lacteus* (Milky Beauty-heads)
- *Chrysocephalum apiculatum* (Common Everlasting)
- *C. semipapposum* (Clustered Everlasting)
- *Cirsium vulgare* (Spear Thistle) (I)
- *Cotula coronopifolia* (Water Buttons) (I)
- *Craspedia* sp. (Tunbridge) (Billy Buttons) (E)
- *Hypochoeris glabra* (Smooth Cat's Ear) (I)
- *H. radicata* (Flatweed, Cat's Ear) (I)
- *Isoetopsis graminfolia* (Grass Daisy)
- *Leontodon taraxacoides* (Hawkbit) (I)
- *Leptorhynchos squamatus* (Scaly Buttons)
- *Leucochrysum albicans* var. *tricolor* (Hoary Sunray)
- *Microseris lanceolata* (Native Dandelion)
- *Podolepis jaceoides* (Showy Podolepis)
- *Scorznera laciniata* (Viper's Grass) (I)
- *Senecio quadridentatus* (Fireweed)
- *Silybum marianum* (Milk Thistle) (I)
- *Solenogyne dominii* (Solenogyne)
- *S. gunnii* (Solenogyne)
- *Sonchus asper* (Prickly Sow Thistle) (I)
- *S. oleraceus* (Sow Thistle) (I)
- *Taraxacum officinale* (Dandelion) (I)
- *Tragopogon porrifolius* (Salsify) (I)
- *Vittadinia cuneata* (New Holland Daisy)
- *V. gracilis* (New Holland Daisy)
- *V. muelleri* (New Holland Daisy)

BORAGINACEAE
- *Cynoglossum suaveolens* (Hound's Tooth)
- *Echium vulgare* (Patersons Curse) (I)
- *Myosotis discolor* (Forget-me-not) (I)

BRASSICACEAE
- *Brassica rapa* (Wild Tumip) (I)
- *Capsella bursa-pastoris* (Shepherd's Purse) (I)
- *Cardaria draba* (White Weed) (I)
- *Erophila verna* (Whitlow Grass) (I)
- *Lepidium hyssopifolium* (Peppercress)
- *Rapistrum rugosum* (Turnip Weed) (I)

CAMPANULACEAE
- *Wahlenbergia stricta* (Bluebell)

CARYOPHYLLACEAE
- *Cerastium glomeratum* (Sticky Mouse-eared Chickweed) (I)
- *Moenchia erecta* (I)
- *Petrorhagia nanteuilii* (Childing Pink) (I)
- *Scleranthus biflorus* (Knawel)
- *S. diander* (Knawel)
- *Silene gallica* (French Catchfly) (I)
- *Spergularia media* (Coast Sandspurrey) (I)

CHENOPODIACEAE
- *Einadia nutans* subsp. *nutans* (Climbing Saltbush)

CLUSIACEAE
- *Hypericum gramineum* (Small St John's Wort)

CONVOLVULACEAE
- *Convolvulus erubescens* (Native Bindweed)
- *Dichondra repens* (Kidney-weed)
- *Wilsonia rotundifolia* (Round-leaf Wilsonia)

CRASSULACEAE
- *Crassula sieberana* (Austral Stonecrop)

DILLENIACEAE
- *Hibbertia riparia* (Guinea Flower)
- *H. serpyllifolia* (Guinea Flower)

DROSERACEAE
- *Drosera peltata* subsp. *peltata* (Sundew)

EPACRIDACEAE
- *Acrotriche serrulata* (Ants Delight)
- *Astroloma humifusum* (Native Cranberry)
- *Lissanthe strigosa* (Peach Berry)

EUPHORBIACEAE
- *Poranthera microphylla* (Small-leaf Poranthera)

FABACEAE (LEGUMINOSAE)
- *Bossiaea prostrata* (Creeping Bossiaea)
- *B. riparia* (Leafless Bossiaea)
- *Daviesia ulicifolia* (Native Gorse)
- *Medicago lupulina* (Black Medic) (I)
- *Medicago polymorpha* (Burr Medic) (I)
- *Pultenaea prostrata* (Dwarf Bush Pea)
- *Trifolium dubium* (Yellow Suckling Clover) (I)
- *T. glomeratum* (Clustered Clover) (I)
- *T. repens* (White Clover, Dutch Clover) (I)
- *T. striatum* (Knotted Clover) (I)
- *T. subterraneum* (Subterranean Clover) (I)
- *Ulex europaeus* (Gorse, Furze) (I)
- *Vicia sativa* (Common Vetch) (I)

FUMARIACEAE
- *Fumaria* sp. (Fumitory) (I)

GENTIANACEAE
- *Centaurium erythraea* (Pink Centaury) (I)
- *Cicendia filiformis* (Slender Cicendia) (I)

GERANIACEAE
- *Erodium botrys* (Long Storks Bill) (I)
- *E. cicutarium* (Common Storksbill) (I)
- *E. moschatum* (Musk Storksbill)(I)
- *Geranium potentilloides* (Geranium)
- *G. solanderi* (Geranium)
- *Pelargonium australe* (Austral Storksbill)

GOODENIACEAE
- *Goodenia lanata* (Native Primrose)
- *Selliera radicans* (Swamp Weed)
- *Velleia paradoxa* (Spur Velleia)

HALORAGACEAE
- *Gonocarpus tetragynus* (Common Raspwort)

LAMIACEAE
- *Marrubium vulgare* (Horehound) (I)

LINACEAE
- *Linum marginale* (Native Flax)

MIMOSACEAE
- *Acacia dealbata* (Silver Wattle)

MYRTACEAE
*Eucalyptus pauciflora* (Cabbage Gum)
OXALIDACEAE
*Oxalis perennans* (Yellow Wood Sorrel)
PLANTAGINACEAE
*Plantago coronopus* (Buck's-horn Plantain) (I)
*P. lanceolata* (Plantain, Ribwort) (I)
*P. major* (Greater Plantain) (I)
*P. varia* (Variable Plantain)
PITTOSPORACEAE
*Bursaria spinosa* (Prickly Box)
POLYGALACEAE
*Rumex acetosella* (Sheep's Sorrel) (I)
*R. crispus* (Curled Dock) (I)
*R. dumosus* var. *dumosus* (Native Dock)
PRIMULACEAE
*Anagallis arvensis* (Pimpernel) (I)
RANUNCULACEAE
*Ranunculus lappaceus* (Buttercup)
*R. prasinus* (Buttercup) (E)
RESEDACEAE
*Reseda luteola* (Mignonette) (I)
ROSACEAE
*Acaena agnipila* (Hairy Sheep's Burr)
*A. echinata* (Sheep's Burr)
*A. ovina* (Australian Sheep's Burr)
*Aphenes arvensis* (Parsley Piert) (I)
*Crataegus monogyna* (Hawthorn) (I)
*Cotoneaster glaucophyllus* (Cotoneaster) (I)
*Rosa rubignosa* (Briar Rose) (I)
*Rubus fruticosus* (Blackberry) (I)
RUBIACEAE
*Asperula conferta* var. *conferta* (Common Woodruff)
*Coprosma quadrifida* (Native Currant)
*Galium aparine* (Goosegrass) (I)
*G. australe* (Tangled Bedstraw)
*G. murale* (Small Bedstraw) (I)
SCROPHULARIACEAE
*Parentucellia latifolia* (Common Bartsia) (I)
*Veronica gracilis* (Speedwell)
SOLANACEAE
*Lycium ferocissimum* (Boxthorn) (I)
STACKHOUSIACEAE
*Stackhousia gunnii* (Gunn's Mignonette) (E)
THYMELAEACEAE
*Pimelea humilis* (Rice Flower)
VIOLACEAE
*Viola hederacea* (Ivy-leaf Violet)

MONOCOTYLEDONS
CYPERACEAE
*Carex breviculmis* (Sedge)
*Isolepis* sp.
*Lepidosperma inops* (Little Sword-sedge) (E)
*Schoenus absconditus* (E)
*S. apogon* (Common Bog-Rush)
IRIDACEAE
*Romulea rosea* (Onion Grass) (I)
JUNCACEAE
*Luzula meridionalis* (Woodrush)
LILIACEAE
*Arthropodium milleflorum* (Vanilla Lily)
*A. minus* (Vanilla Lily)
*Dianella longifolia* var. *longifolia* (Flax Lily)
*D. revoluta* var. *revoluta* (Flax Lily)
*Hypoxis hygrometrica* (Golden Weather-glass)
*Wurmbea dioica* subsp. *dioicia* (Early Nancy)
ORCHIDACEAE
*Corybas* sp. (Helmet Orchid)
*Diuris lanceolata* (Golden Moths)
*Microtis unifolia* (Onion Orchid)
*Prasophyllum odoratum* (Scented Leek Orchid)
*Pterostylis commutata* (Ruddy Greenhood) (E)
*Spiranthes australis* (Austral Ladies Tresses)
*Thelymitra pauciflora* (Slender Sunorchid)
POACEAE
*Agrostis aemula* var. *aemula* (Blown Grass)
*A. capillaris* (Brown-top Bent) (I)
*Aira caryophyllea* (Silvery Hair Grass) (I)
*Arrhenatherum elatius* (Oatgrass) (I)
*Avena fatua* (Wild Oat) (I)
*Briza minor* (Lesser Quaking Grass) (I)
*Bromus catharticus* (Prairie Grass) (I)
*B. diandrus* (Ripgut Brome) (I)
*B. hordeaceus* (Soft Brome) (I)
*Cynosurus echinatus* (Dog's Tail Grass) (I)
*Dactylis glomerata* (Cocksfoot) (I)
*Danthonia caespitosa* (Wallaby Grass)
*D. carphoides* var. *angustior* (Wallaby Grass)
*D. pilosa* (Wallaby Grass)
*D. setacea* (Wallaby Grass)
*D. tenuior* (Wallaby Grass)
*Deyeuxia quadriseta* (Bent Grass)
*Dichelachne crinata* (Plumegrass)
*D. rara* (Plumegrass)
*Distichlis distichophylla* (Australian Salt Grass)
*Ehrharta stipoides* (Weeping Grass)
*Elymus repens* (Twitch Grass) (I)
*E. scaber* (Common Wheatgrass)
*Holcus lanatus* (Yorkshire Fog Grass) (I)
*Hordeum marinum* (Ryegrass) (I)
*H. murinum* (Ryegrass) (I)
*Lolium perenne* (Perennial Ryegrass) (I)
*Pentapogon quadrifidus* (Five-awned Speargrass)
*Poa annua* (Winter Grass, Annual Poa) (I)
*P. bulbosa* (Bulbous Meadow Grass) (I)
*P. hookeri* (Tussock Grass)
*P. labillardierei* var. *labillardierei* (Tussock Grass)
*P. pratensis* (Kentucky Blue Grass) (I)
*P. rodwayi* (Tussock Grass)
*Puccinellia stricta* (Australian Saltmarsh Grass)
*Stipa flavescens* (Speargrass)
*S. nodosa* (Speargrass)
*S. semibarbata* (Speargrass)
*S. stuposa* (Speargrass)
*Themeda triandra* (Kangaroo Grass)
*Vulpia myuros* (Rat's Tail Fescue) (I)
XANTHORRHOEACEAE
*Lomandra nana* (Pale Mat Rush)

PTERIDOPHYTES
SINOPTERIDACEAE
*Cheilanthes austrotenuifolia* (Rock-fern)

# AGE CONSTRAINTS FOR CLASTIC SEDIMENTS FROM TWO CAVES IN THE JUNEE–FLORENTINE KARST, TASMANIA

by Rolan Eberhard

(with one table and three text-figures)

EBERHARD, R., 1997 (31:viii): Age constraints for clastic sediments from two caves in the Junee–Florentine karst, Tasmania. *Pap. Proc. R. Soc. Tasm.* 131: 67–72. ISSN 0080-4703. Environment Australia, PO Box 787, Canberra, ACT; Australia 2601; formerly Forestry Tasmania.

Uranium-thorium dating of speleothems from two caves in the Junee–Florentine karst, Tasmania, provides some age constraints for associated clastic sediments including coarse dolerite-rich fluvial gravels, which underlie the three oldest dated speleothems. The results suggest minimum ages of 15 ± 5 ka, ~325 ka and >350 ka (two dates) for the gravels, implying that they are considerably older than the early Last Glacial age suggested previously for some fluvial gravels in other Junee–Florentine caves.
**Key Words: karst, caves, cave sediments, speleothems, radiometric dating, Pleistocene, Tasmania.**

## INTRODUCTION

The Junee–Florentine karst area in central southern Tasmania is the location of numerous caves, many of which contain extensive alluvial deposits of allogenic origin. In particular, caves along the eastern margin of the karst with catchments on the Mount Field massif tend to be at least partially infilled with coarse alluvial gravels, predominantly rounded to angular dolerite clasts. It has been suggested that many former inflow caves remained quiescent for extended periods in the Pleistocene, due to blockage by clastic fills (Goede 1973). Application of radiometric dating methods to secondary carbonates that occur in association with the allogenic sediments provided an opportunity to obtain a preliminary indication of the possible ages of some of the cave deposits.

Previous work on cave sediments in the Junee–Florentine area has focussed on sites of archaeological and palaeontological interest, including Beginners Luck Cave, a relict stream cave located at 400 m a.s.l. in the Florentine Valley. The cave is characterised by thick deposits of coarse dolerite gravels and sands, that almost completely choke some of its passages. Beginners Luck Cave lacks a perennial stream today but appears to have been fed by significant runoff from slopes in the vicinity of Mount Dawson (1062 m — part of the Mount Field massif) when the cave fills were deposited. Various lines of evidence led Goede & Harmon (1983) to conclude that Beginners Luck Cave and some other Tasmanian caves had been affected by a period of widespread alluviation between about 75 and 50 ka. They refer to this as the "Beginners Luck Alluvial Phase". Much of the evidence for this age rests on their interpretation of weathering rind data for dolerite clasts within the alluvium at Beginners Luck Cave.

Many Tasmanian caves contain extensive deposits of allogenic alluvial fills ranging from sands and silts to large boulders. The alluvial fills are clearly relict in many cases, being located in passages that are no longer hydrologically active or comprising clasts that are too coarse to be accounted for by contemporary cave streams. Some of the deposits have been interpreted as Pleistocene fluvial and glaciofluvial sediments, although few sedimentary sequences have been dated with precision (Burns 1960, Goede 1969, Goede & Murray 1977, 1979, Goede & Harmon 1983, Kiernan 1983, 1984, 1991a, Houshold & Spate 1990).

## THE JUNEE–FLORENTINE KARST

The Junee–Florentine karst is located at approximately latitude 42°40'S and longitude 146°30'E (fig. 1). The karst is formed in massive, folded Ordovician limestones, that underlie the major portion of the Florentine Valley. Contiguous limestone outcrops extend south along the western slopes of the Mount Field massif, approaching the township of Maydena ("Junee area") in the Tyenna River catchment. The karst is characterised by well-developed surface karst landforms and extensive cave systems (Goede 1973, Hume 1991, Eberhard 1994, 1996).

The karst is surrounded by mountainous areas with high points at the summits of Mount Field West (1434 m), Wylds Craig (1337 m) and Mount Mueller (1245 m). These mountains and associated elevated areas have been subject to glacial and periglacial action in the Pleistocene. Periglacial processes are still active to a minor extent at higher altitudes in the area. On the basis of current evidence, most of the karst remained free of the direct action of glacial ice in the Pleistocene. Evidence that glaciers descended to the level of the karst, which reaches a maximum altitude of about 800 m a.s.l., appears to be confined to the upper Florentine Valley, south of Tim Shea, and the Lawrence Rivulet area (Corbett 1964, Peterson 1969, Brown *et al.* 1989). Some caves with catchments on the slopes of the glaciated Mount Field massif are likely to have been subject to glacial meltwater flows and glaciofluvial sedimentation. Seasonal snowmelt continues to be a significant source of runoff in the catchment of these caves. Thick, dolerite-rich diamictons mantle the karst on the slopes of the massif and are interpreted as primarily the result of enhanced periglacial slope instability during Pleistocene cold climate episodes.

The karst is now covered by wet sclerophyll and mixed forests, some of which have been harvested for timber in recent decades. The present climate of the area is moist and cool; records from Maydena (267 m a.s.l.), near the southeastern margin of the karst indicate mean maximum

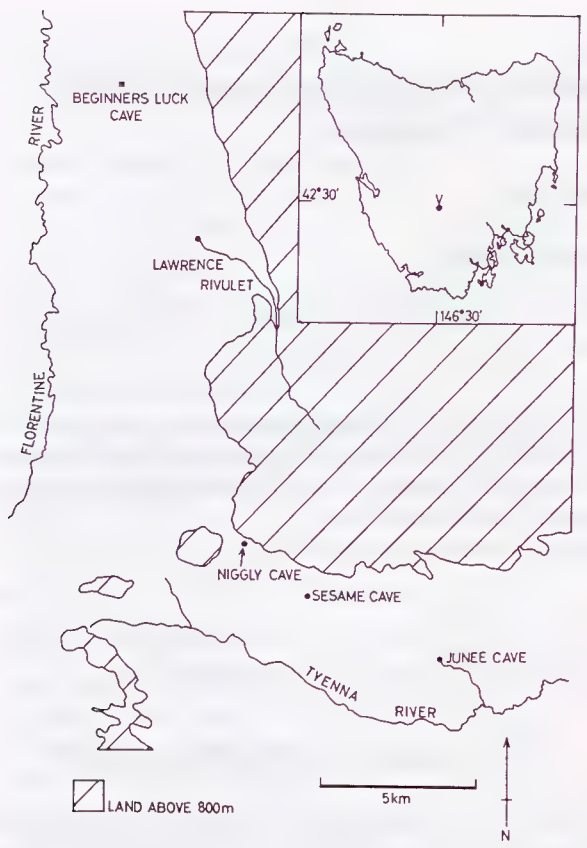


*FIG. 1 — Locality map showing caves referred to in the text.*

and minimum annual temperatures of 15.7°C and 5.0°C and a mean annual precipitation of 1219 mm (Bureau of Meteorology 1988).

## CAVE DEPOSITS

### Niggly Cave

Niggly Cave is an active inflow cave located at 740 m a.s.l. on the western slopes of Florentine Peak in the Mount Field National Park. The cave descends steeply to a base-level conduit at an altitude of about 350 m a.s.l. and is a confirmed tributary of the Junee Cave outflow in the Tyenna River catchment (Hume 1991). The upper part of the cave is a horizontal streamway, sections of which contain a prominent calcite false floor. The false floor comprises a 100–200 mm thickness of flowstone that completely bridges the 1–2 m wide streamway in places. The false floor is suspended approximately 1 m above the base of the streamway and the minor perennial stream which it now contains. Rounded dolerite cobbles, up to 200 mm diameter, occur along the base of the passage and are cemented to the underside of the false floor. There is little evidence of ongoing clastic sedimentation, and the larger dolerite clasts appear beyond the competence of the contemporary cave stream.

The development of the false floor is presumed to reflect the following sequence of events: (1) accumulation of allogenic alluvium on the floor of the passage, (2) reduction or cessation of stream activity, followed by flowstone deposition onto the clastic substrate, (3) resumption of stream flow, accompanied by the flushing away of clastic material temporarily sealed beneath the flowstone. A similar mode of formation is postulated for flowstone remnants which bridge passages in Tunnel Cave, Benmore, New South Wales (Frank 1973).

Fragments of flowstone resulting from natural collapse and breakage of the Niggly Cave false floors were sampled for radiometric dating (sample N1).

A second calcite sample was obtained downstream of the false floor in an abandoned vadose canyon containing remnants of an interbedded sequence of fine gravels, sands and clays. These sediments include frequent calcite bands and survive on rock ledges high in the canyon. A 50 mm stalagmite formed upon the clastic sequence was sampled (sample N2).

Sample collection sites in Niggly Cave and the stratigraphy of sedimentary deposits associated with the dated speleothems are shown in figure 2.

### Sesame Cave

Sesame Cave is a former inflow cave located at 570 m a.s.l. some 2 km southeast of Niggly Cave and also on the western slopes of the Mount Field massif. The cave descends in a series of vertical steps interspersed with sections of horizontal passage, reaching a depth of more than 200 m below the higher of its two entrances. Sesame Cave is located within the karst catchment of Junee Cave and is presumed to be part of an extensive conduit network associated with that cave (Eberhard 1994).

The upper passages in Sesame Cave contain a sizeable chamber where a deeply eroded sequence of bedded allogenic sediments at least 7 m thick is present. Four broad lithostratigraphic units may be differentiated within the deposit:

(1) A basal unit ~1.8 m thick, consisting of subangular to moderately rounded allogenic gravels in an orange clay matrix. The principal constituent rock type of the gravels is dolerite in clasts up to 300 mm diameter. Dolerite gravels exposed at the surface of the deposit appear to be deeply chemically weathered, to the extent that some of the larger clasts are almost completely decomposed. This unit is considered to be an alluvial deposit that would have required the action of a high-energy stream to reach its present location.

(2) A heterogeneous sequence of interbedded fine gravels, sands and clays, with a total thickness of about 1 m. Lenses of calcite up to 40 mm thick are frequent and, in places, show evidence of impressions of polygonal mud cracks. This unit appears to unconformably overlie (1) and is considered to reflect relatively low-energy fluvial conditions interspersed with periods of carbonate deposition.

(3) A ~1 m thickness of sizeable limestone blocks of angular form, that have a chaotic arrangement. Interstices between the blocks are filled with finer sediment, similar to that of the overlying unit (4). This unit is considered to be a cave collapse facies.

(4) An upper unit comprising sands and fine gravels with a few clay lenses. The sediments are laminated and are in the order of 4 m thick. This unit is considered to be fluvial in origin.

A calcite horizon towards the base of (2) was sampled (sample S2).

The lower section of Sesame Cave is characterised by a

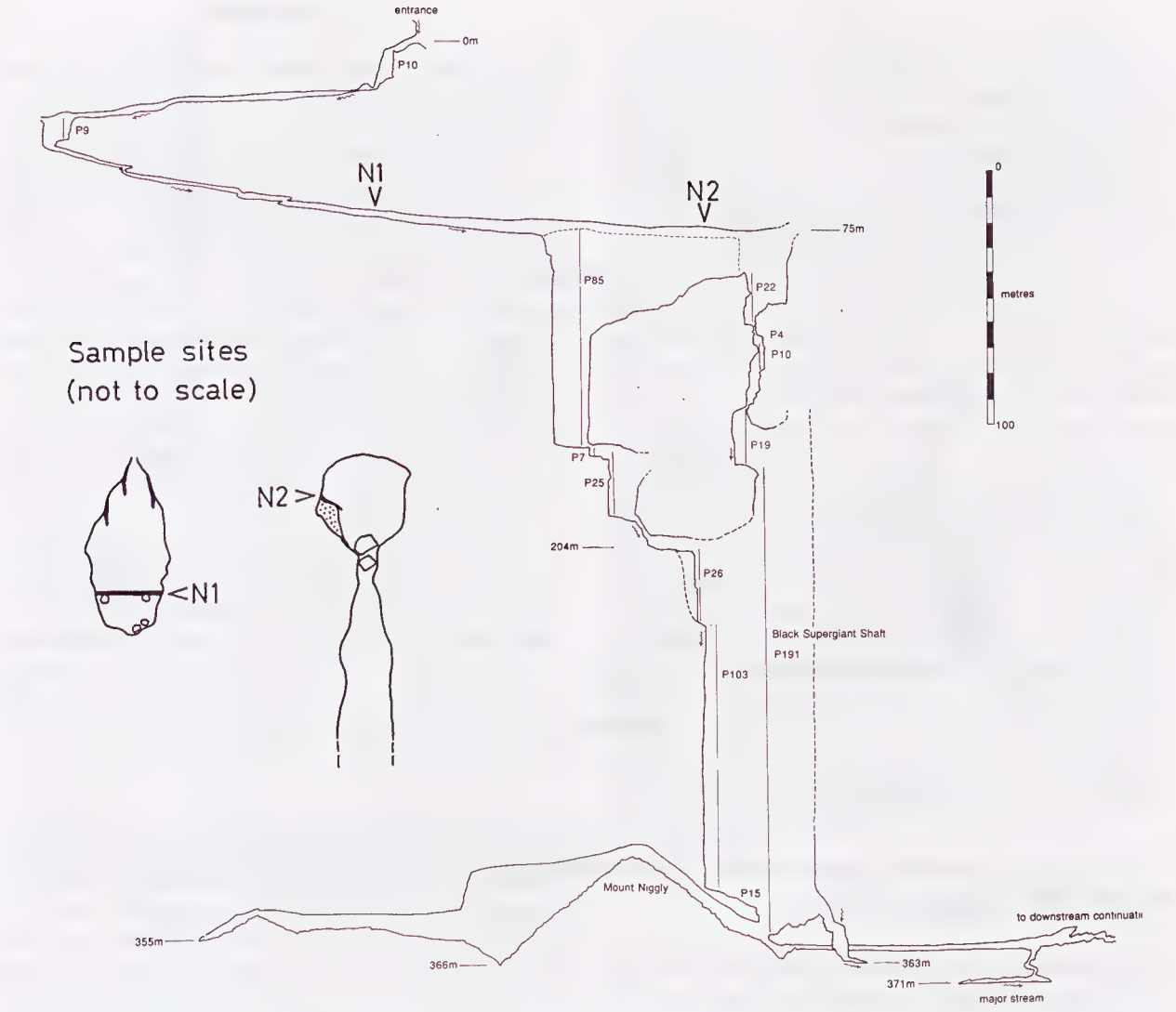


*FIG. 2 — Niggly Cave showing sample collection sites and straigraphy of the dated deposits. The cave is depicted in vertical cross-section (after Eberhard 1994).*

deeply incised vadose canyon where a calcite false floor, similar to that in Niggly Cave, is present. A similar sequence of events is assumed to have formed the false floors at both sites. Whereas the Niggly Cave false floors reach a maximum thickness of about 300 mm, the Sesame Cave floors are more massive, reaching a thickness of 1.5 m in places. Flowstone at the base of the false floor was collected for dating (sample S1).

Allogenic clasts, embedded in the underside of the Sesame Cave false floors, indicate that the original substrate on which the flowstone was deposited included well-rounded dolerite gravels, up to boulder size. One extant clast has a diameter of ~1 m; other clasts are in the order of 100–300 mm diameter. Most of the original deposit has been lost to erosion.

Sample collection sites in Sesame Cave and the stratigraphy of sedimentary deposits associated with the dated speleothems are shown in figure 3.

## RADIOMETRIC DATING

Radiometric determinations were undertaken at the Australian Nuclear Science and Technology Organisation Environmental Radiochemistry Laboratory (uranium series) and at Beta Analytic Inc. (USA) (radiocarbon). All of the samples were massive crystalline deposits of low permeability and lacking obvious exogenic exclusions. This reduces the possibility of misleading results, due to preferential leaching of $^{234}U$ by cave waters, resulting in too great an age being calculated (Harmon *et al.* 1975, Gascoyne *et al.* 1978). Uranium levels in all samples were found to be sufficient for uranium series dating. Results are presented in table 1.

An initial attempt to date the N1 sample, using the $^{14}C$ method, revealed an age in excess of 43.5 ka (Beta-69657) and beyond the limit of dating by that method.

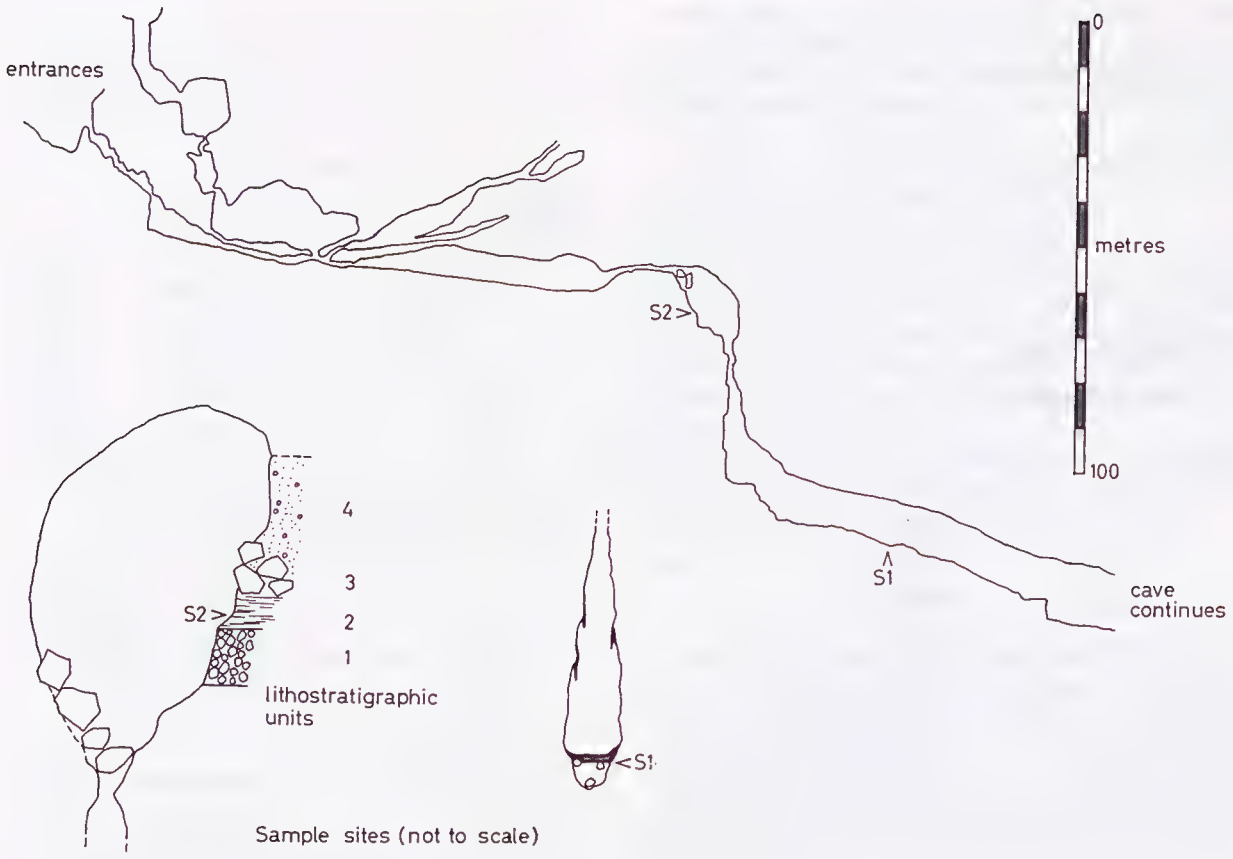


*FIG. 3 — Sesame Cave showing sample collection sites and stratigraphy of the dated deposits. The cave is depicted in vertical cross-section (after Tunny* et al. *1982).*

TABLE 1
**Uranium concentrations, isotope activity ratios and calculated ages for speleothems**

| | Sample* (lab no.) | | | |
|---|---|---|---|---|
| | N1 (LH3572) | N2 (LH3573) | S1 (LH3574) | S2 (LH3575) |
| U (ppm) | 0.4332 | 0.9227 | 0.06008 | 0.3748 |
| error | 0.0192 | 0.0359 | 0.00589 | 0.0176 |
| $^{230}Th/^{232}Th$ | 146.6 | 22.55 | 15.46 | 18.52 |
| error | 53.5 | 8.38 | 4.84 | 3.27 |
| $^{230}Th/^{234}U$ | 1.288 | 0.1403 | 1.004 | 1.061 |
| error | 0.075 | 0.0129 | 0.123 | 0.072 |
| $^{234}U/^{238}U$ | 1.3201 | 0.7708 | 1.211 | 0.9058 |
| error | 0.3120 | 0.0438 | 0.0163 | 0.0612 |
| Calculated age (ka) | >350 | 15 ± 5 | 325 ± 500/100 | >350 |

* N1, N2 from Niggly Cave; S1, S2 from Sesame Cave. All from Junee–Florentine karst, Tasmania.

## DISCUSSION

Samples N1 and S1 were obtained from flowstone laid down on coarse allogenic cave fills. The size of some extant clasts suggests a high-energy stream environment, particularly at the S1 site. The radiometric determinations imply deposition of the clastic sediment prior to 350 ka at Niggly Cave and prior to ~325 ka at Sesame Cave. Formation of the S1 flowstone at about 325 ka may suggest a significant phase of chemical sedimentation at this site during the interglacial period of marine isotope stage 9, as globally defined. An interglacial environment would be consistent with the large scale of the Sesame Cave flowstone deposit, taking into account evidence from speleothem growth-frequency studies that interglacial periods were times of increased speleothem activity (Atkinson *et al.* 1978, Goede & Harmon 1983). However, the S1 result is close to the limit of uranium series dating and needs to be interpreted cautiously.

Sample S2 was obtained from a calcite horizon within a relatively complex sedimentary sequence elsewhere in Sesame Cave. The dated calcite forms part of a sequence of interbedded fine gravels, sands and clays, which unconformably overlies coarse allogenic gravels with a high proportion of moderately rounded dolerite clasts. Both deposits are interpreted as primarily fluvial in origin and relate to events that occurred prior to 350 ka on the basis of the S2 result. The infinite date for sample S2 does not constrain the age of the overlying sediments, which include a presumed cave collapse facies and alluvial sands and gravels.

Radiometric evidence concerning the ages of the N1, S1 and S2 speleothems and associated clastic deposits bears comparison with a uranium series date of >400 ka, obtained by Goede & Harmon (1983), for speleothem material overlying gravelly alluvium in Exit Cave at Ida Bay in southern Tasmania. However, whereas the Exit Cave alluvium now lies 25 m above the active stream, in a cave considered to have developed over a long and complex evolutionary history (Goede 1969, Household & Spate 1990, Kiernan 1991b), the morphology and topographic context of the Junee–Florentine caves containing the dated sediments are less obviously suggestive of great age. Niggly Cave is an active inflow, developed below an entrance at the unconformity between the limestone and overlying impervious strata. In this situation, allogenic runoff from the overlying rocks could be expected to facilitate karstification and the rapid initiation of cave passages under vadose conditions. Sesame Cave is no longer an active inflow, although the passages within it are dominantly vadose in character and appear to have originated in response to allogenic runoff sinking underground, some distance below the unconformity. Sesame Cave is located in an area where the bedrock is generally mantled by deep slope deposits, which have promoted surface drainage across the limestone in a number of instances. Here, variation in the thickness of the slope mantles, rather than the site of the unconformity, is interpreted as a primary control on the location of streamsinks.

Goede (1973) has suggested that the blockage of streamsinks during cold climate episodes has been an important factor in the development of an extensive system of dry valleys developed below present and former streamsinks in the Junee area. In recent times, landslides that appear to be associated with the destabilising effects of forest fires have resulted in the partial blockage of at least two streamsinks on the slopes of Mount Field West and Wherretts Lookout (Eberhard 1992, 1994). Blockage of inflow points may well have occurred on multiple occasions at Niggly Cave, with fluvial excavation of infilling sediments (or the initiation of new conduits) enabling subterranean conduits to recapture the drainage. This scenario would constrain the rate of cave development in an otherwise favourable situation and may have facilitated the survival of cave sediments potentially susceptible to erosion by fluvial processes. In the case of Sesame Cave, abandonment of the inflow point is probably explicable in terms of the upstream retreat of the sinking point and its capture (or recapture) by other subterranean conduits, developed below entrances at higher altitude.

Sample N2 provides a minimum age for remnants of bedded sands and gravels of presumed fluvial origin in an abandoned vadose passage in Niggly Cave. The radiometric result implies that the clastic sediments are older than ~15 ka by some unknown amount, probably considerably so, given their location in a passage that is now stranded high above the level of active streamways. The age of the dated speleothem material conforms to a pattern of Late Pleistocene carbonate deposition in Tasmanian caves, particularly between 30 and 10 ka, established by Goede & Harmon (1983). These authors report a cluster of dates at 15–19 ka, which they interpret as reflecting rapid climatic amelioration, following a Last Glacial Maximum at about 18 ka.

## CONCLUSIONS

Allogenic alluvial fills, ranging from coarse dolerite-rich boulders to sands and clays, are a prominent feature of caves with catchments on the slopes of Mount Field massif in the Junee–Florentine karst area. Radiometric dating of associated secondary carbonates indicates that alluviation occurred prior to ~325–350 ka in at least two caves. This contrasts with a presumed early Last Glacial age for fluvial gravels in nearby caves at lower altitude in the Florentine Valley, which has been suggested primarily on the basis of weathering rind evidence (Goede & Harmon 1983). Clearly, there is considerable scope for further investigation of the cave sediment record of the Junee–Florentine karst. It is now evident that some of the caves are of considerable antiquity, and that they contain sedimentary sequences which extend well back into the Pleistocene.

## ACKNOWLEDGEMENTS

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# MAGNETIC ROCKS — THEIR EFFECT ON COMPASS USE AND NAVIGATION IN TASMANIA

by David Leaman

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The common and uncritical use of the magnetic compass by orienteers and walkers in Tasmania may lead to severe error. Rocks in many localities are intensely magnetised and their local field can strongly influence the pointing of a compass. Repeated observation against transect alignments may be necessary to minimise the problems.
**Key Words: magnetics, compass, navigation, dolerite**

## THE MAGNETIC FIELD

The magnetic field in Tasmania has a normal intensity of about 61 500 nanoteslas (nT) and is oriented upward at 71° (inclination) and about 14° east of north (declination). All values, especially declination, may change slowly with time. This is a strong field in global terms, and it should promote a stable compass, where the needle is properly compensated. The vertical component of this field is about 58 150 nT and the horizontal component about 20 020 nT.

The orientation of the field in place means that, at the time of writing, any compass needle will point approximately 14° east of true north when reading its own north. This value must be ***added*** to any compass reading in order to plot courses on a normal geographic base map.

If, however, the horizontal component of the field was rotated to another declination, then the compass needle would be swung away from the proper orientation for magnetic north across Tasmania. If the causative effect were local and the compass, or observer, were moving (as on a ship, aircraft or walking), then the compass needle might be observed to swing, be sluggish or rotate. These are common observations and often noted when the compass has been mounted in a vehicle and is clearly visible.

Either of two characteristics of the magnetic field is required if a compass, which is a relatively crude instrument, is to be affected. These are that the intensity of the field be increased substantially at a different declination - possibly very locally, or that there be abrupt changes in the orientation and magnitude of gradients in the local field. The first condition may arise from permanent magnetisation in the rocks present, while the second may be due to local distribution or shape of rock exposures.

## SOME TASMANIAN ROCKS

Most rocks are either permanently magnetised and/or magnetisable in the Earth's magnetic field. Very few, however, are magnetised, and most others are unable to induce a significant effect in the field. The magnetically important rocks — in a navigation context — include iron ores, ultramafics, and crucially (for Tasmania) basalts (mainly Tertiary in age) and the ubiquitous Jurassic dolerite.

Iron ores are restricted to small areas in northwestern Tasmania; near Savage River, Rocky River and Hampshire. Terrain in these regions is rarely cloud-bound and is sufficiently distinctive to ensure that any compass problems are not potentially life threatening. Ultramafic rocks, similarly, are relatively rare and of small volume but have been known to cause problems in isolated locations near Adamsfield, Andersons Creek (M. Banks, M. Brown, pers. comm.), McIvors Hill (P.W. McCartney, pers. comm.), Heazlewood River and other localities as shown in figure 3.6 (p. 70) of the 1989 edition of the *Geology and Mineral Resources of Tasmania,* published by the Geological Society of Australia.

Basalt and dolerite are common rocks, and each may generate modest changes in the ambient field, due to their mineral content, which includes ilmenite and magnetite. A magnetic field may be affected by these minerals. These rocks rarely generate changes in excess of 1000 nT, and most occurrences do not modify the orientation of the field vector significantly. Dolerite is up to five times more magnetic than basalt, due to the minerals present, rock texture and crystal size. Both rocks are igneous and have crystallised from high temperature. The ambient magnetic field at the time of cooling (8–60 Ma for basalts and 160–170 Ma for dolerite) can be partially or wholly "frozen" into the rock, which may then act as a permanent magnet. This permanent or thermo-remanent effect may then be superimposed on the induction effect of the ambient field already acting on the minerals present. Thus, two magnetic field vectors may interact near such rocks. The net result depends on the strength of the remanent field and the amount of material which is susceptible to the present field. Weathering may destroy the permanent effect and change the capacity of the rock to induce a local field. A range of outcomes is possible and common. The compass needle responds to the total field actually generated.

Weathering of ferro-magnetic minerals may also produce weakly magnetic hydrous iron oxides (such as goethite, maghemite), and some ironstone gravels may be magnetic. Usually, however, these materials do not generate the intense effects required to deflect a compass needle.

Dolerite intrusions are usually large bodies, and significant compositional and textural changes may be observed within them. The most magnetic parts of the intrusions, in terms of induction effects, occur where crystals are large and much magetite is present. These conditions are usually found in the upper quarter of a sheet or near feeders. Most strong remanent effects, however, are related to the finer-grained parts of the intrusions and are often confined to zones near contacts with either country rock or other

intrusions (e.g. Leaman 1972). It is possible to generate anomalies of tens of thousands of nanoteslas in these conditions although 2000-5000 nT is more usual.

Compasses are not usually deflected greatly by this vector interplay, since the Jurassic and Tertiary magnetic fields were oriented much like the modern field — but with a steeper inclination — and the modern induction effect tends to swamp any permanent magnetisation present. The declination was not the same, however, and, consequently, if the intensity of the preserved field is high, then the remanence may dominate the magnetic properties of the rock. In such a case, that rock will twist the local field vector away from the present day magnetic north toward the preserved vector. Up to 40° is possible for some dolerites (note data in Irving 1956, and Schmidt & McDougall 1977). Fortunately, this dominating condition appears to be quite rare and the shift is usually less than 5°. The remanent vector may sometimes oppose the modern vector (Leaman 1978) but, in most cases, it has a similar orientation, and the combination of vectors merely results in a decrease in local intensity.

Both rocks, however, occur on the land surface across wide areas, and a much more significant source of variation in their magnetic properties (especially for dolerite) is due to their elevated position in the landscape and the geometry of the exposures. Hill tops, promontories and many exposures on plateaux may have been struck by lightning on several occasions. A lightning strike generates a massive local electric current with considerable heating, and the associated transient magnetic field may entirely reset the normal magnetic properties of the rock. Since the currents may flow subhorizontally across the surface, the orientation of the field in the now reset, intensely magnetised rock (a rock very susceptible to such changes, due to its mineralogy) may be very different from the ambient field or extremely variable. The effect of a major lightning strike is permanent, and a large number of detectable and anomalous locations may exist across those parts of Tasmania where basalt or dolerite is exposed.

Many examples could be quoted of the type of changes observed. Four, including two new sites recorded by the author, are given to indicate the nature and scale of the effects possible.

(1) Rosny Hill, Hobart. Exposed rocky hill, dolerite. Height 100 m a.s.l. Several lightning strikes, each producing local changes with effect across radii up to 100 m (Watt 1971, Leaman 1972).

(2) Tasman Peninsula: Lichen Hill, north Tatnells Hill. Ridge line, sheltered col, little dolerite outcrop. Height 450 m a.s.l. Magnetic variation of north–up to 40° over a ridge distance of 80 m at least.

(3) Mt Hull west, near Collinsvale. Ridge line, exposed dolerite rock outcrops. Height 750 m a.s.l. Magnetic variation of north–20 to 70°, depending on position among the outcrops. Affected area at least 16 x16 m.

(4) Hartwell Cove south, near mouth of Wanderer River, western Tasmania. Area of Cambrian basalts. Chapman (1990: 110) has reported variations of 5° to 25° and advises that walkers avoid compass use in the area.

## COMPASS TECHNIQUE

The examples suggest that problems leading to potentially serious errors might be endemic, given the common use of, or need to use, a compass — as in cloud on the central plateau (a dolerite area) or in dense forest.

Errors less than 5° or 10° may be serious in many situations; especially if a bearing is taken on a landmark, and then a route is traversed for some distance toward it before rechecking the bearing. Where visibility is restricted, it is more usual to continue observation of the compass, follow a bearing as displayed and to adjust the route continuously. In such cases, any local anomaly or distortion of bearing may not lead to a serious loss of position, unless there has been an unfortunate conjunction of observation sites and exposed, affected outcrops. Many such sites may exist on some ridges or hill tops (e.g. Lichen Hill or Mt Hull).

There is only one safe approach to compass navigation in all of central Tasmania and much of eastern and south-eastern Tasmania. This is never to assume that the compass is reliable: continue to sight objects or trees and check the consistency of readings along transects (an alignment of two trees or features) for distance segments of at least 100–150 m — the longer the better. Since most intense anomalies have radii of influence less than 100 m they will be recognised and the background field orientation confirmed. Sightings from hill tops or bare rock exposures should be checked often.

## HISTORICAL ADDENDA

Some historical notes may be added to this discussion.

Tasman recorded changes in his compass while sailing toward Mt Zeehan in 1642. His first observations were possibly near or beyond the edge of the continental shelf (Heeres 1985: 26); the needle was in motion. This is not readily explained in terms of geology, due to its position, but may indicate a magnetic storm or aurora. Two days later, he observed smaller changes in sight of land, a fact which so perturbed him and his crew that a vote was called, in order to decide whether to proceed, and the ship stood off that night (Heeres 1985). The inferred cause: Cambrian ultramafics on the continental shelf at a depth of about 60 m. It may be noted here that some ultramafic rocks may influence a compass at a range of up to 1000 m.

On 30–31 May 1804, Robert Brown climbed Mt Wellington (Brown 1804, Vallance 1990). He fell and sprained his foot at the summit. Whilst incapacitated, he undertook some magnetic observations with his compass and recorded in his diary that two stones (dolerite) right at the summit were able to generate swings of up to 180°. This influence, however, did not extend much more than 0.05 m from the surface of the rocks. This result might be considered the normal reaction of a compass to these rocks which, in typical circumstances where an observer is standing with the compass, might not have any notable influence.

Matthew Flinders also noted similar anomalies and compass deviations between Betsey Island and the Iron Pot, near the mouth of the River Derwent, during his exploratory surveys (Flinders 1814). It appears that the observations date from his 1798 cruise in the *Norfolk*.

There is no published expansion of his notes, but the *Australian Pilot* (1918, 1st ed., and 1969, 5th ed.) and all older charts (e.g. AUS 171, 794 pre 1975) locate the disturbance 3.2 km southeast of the Derwent Light, bearing 120° true. Compass deflections between 17° and 26° have been recorded.

The area was resurveyed in 1973 and deviations of up to 25° confirmed (Leaman 1975) in less than 20 m of water. Several features were defined and mapped (not one only, as marked on older charts), and most were associated with slightly shallower water, indicating some variation in sea-floor structure or composition. Volcanic necks ( Tertiary basalts) exposed on the bay floor were inferred as the cause. The horizontal component in this zone is the dominant element of the magnetic field, and this accounts for sluggish compass responses and offset compass bearings. The check survey found that the main feature lay 1 km NNW of the officially charted cautionary note.

Any vessel crossing Storm Bay from the southeast, to clear the Iron Pot, could pass through the anomalous region. If a course of 300° was held from south of Betsey Island, and the compass was the only navigational aid, then the possible deflection of 25° would lead to a grounding at the west end of Hope Beach. The course actually run could lead, by following the compass, over at least two features, and the resultant deflection in course could be much greater.

Given this information, we may speculate about the contribution of magnetic effects to the wreck of the *Hope* in the early hours of Sunday, 29 April 1827. The events of that night have been recounted by O'May (1955), but some essential details may be summarised. The pilot boarded the vessel south of Betsey Island, at sunset, in light airs. The ship was making very little way. The night was very dark, and rain became heavy. Visibility was very poor. The ship had arrived in Storm Bay from Sydney and sailed directly into the anomalous zone, in order to clear the Iron Pot. The court of enquiry dwelled at length on the sobriety and competence of the pilot; the Captain had yielded the ship. The court assigned the cause of the wreck to a visual mistake — that of accepting the low profile of the neck beach for the river mouth, even though the pilot was said to be familiar with the area.

Perhaps there is an alternative explanation.

Flinder's observations may have been known in Hobart Town (as a result of comment by him in 1798 or later in Sydney), but it cannot be established that either the local pilot or the Captain of the *Hope* possessed knowledge of the feature or carried a chart bearing his warning. The records of enquiry make no comment about charts or warnings, and it is probable they were ignorant of the danger. This factor was not considered, or not considered relevant. The evidence adduced in court showed that the ship made very little way throughout the night, and that visibility was very poor at all times. The pilot would have known the required bearing to clear Cape Direction, having sighted this before sunset, and would have then held, conservatively, that bearing. It would have been about 300°. The beach and surf were not seen until the ship struck, not long before dawn. It is most unlikely that the pilot mistook any landforms — he probably saw none all night.

Suppose, however, the pilot (and the Captain on his nocturnal visits to the bridge) used the compass throughout. The vessel may then have been taken inexorably onto the beach. The very slow passage during the night could have contributed to the disaster, since all adjustments of the compass would have been subtle and imperceptible. Although this possible cause of the disaster is not mentioned in the official proceedings of the day, could it have been realised soon after? The Derwent Light was installed five years later, and the visual impact and guidance it afforded would then have obviated any further need for compass dependence in such conditions. Or was the construction of the light based on the belief that visual factors were the sole cause? The compass deflection explanation best accords with the recorded facts relating to that fateful night. There have been no subsequent wrecks in the area.

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# GRAVITY SURVEY AND STRUCTURE OF THE FORESTIER PENINSULA, SOUTHERN TASMANIA

by David Leaman

(with 13 text-figures)

LEAMAN, D.E.., 1997 (31:viii): Gravity survey and structure of the Forestier Peninsula, southern Tasmania. *Pap. Proc. R. Soc. Tasm.* 131: 77–84. ISSN 0080–4703. Leaman Geophysics, GPO Box 320C, Hobart, Tasmania, Australia 7001 and Geology Department, University of Tasmania, GPO Box 252-79, Hobart, Tasmania, Australia 7001.

A gravity survey coupled with review of regional mapping has shown that the widespread exposure of Jurassic dolerite across the Forestier Peninsula is due largely to repetition of a thick sheet by gently ramped Tertiary fault-blocks. Feeders for the sheet appear to be located near the centre of the peninsula and to be related to concealed pre-Permian structures, such as granitoid margins. At least two major fault zones were eroded during the mid Tertiary and these, as well as the peninsula ties to mainland Tasmania and the Tasman Peninsula, now consist of Tertiary materials covered by Recent sands. The western edge of the East Tasmanian batholith extends approximately north–south beneath the centre of the peninsula.

**Keywords: Tasmania, dolerite, structure, Forestier Peninsula, faulting, intrusion.**

## INTRODUCTION

This paper documents the first semi-regional gravity survey and structural interpretation of the Forestier Peninsula (fig. 1).

Previous geological work has been largely limited to regional mapping of the main body of the peninsula (Gulline 1982, 1984), sketch mapping of the Eaglehawk Neck area (Banks *et al.* 1989) and some discussion of aspects of the dolerite intrusions along the eastern coastline (Leaman 1978, 1997). All previous geological maps of the area have been found to be flawed, mainly due to problems of windblown sand cover and talus deposits, coupled with rapid reconnaissance methods. A revision is offered in this paper.

Only two significant large-scale gravity surveys have included the peninsulas of southeastern Tasmania; the road-based regional survey of Johnson (1972) and the widely spaced helicopter survey of Zadoroznyj (1975). Neither survey was able to define any local structures or adequately define regional character, although the Tasmanian data base has depended on such data in this area (e.g. Leaman *et al.* 1980, Leaman & Richardson 1989). The regional data previously available were supplemented by a single detailed traverse near Dunalley (Leaman 1973). The survey discussed here provides a regular and widely distributed network which, when coupled with a refined geological base map, allows comprehensive structural analysis.

Structural interpretation has been focussed upon definition of regional features; fault blocks, fault patterns, dolerite intrusions, Tertiary basins, basement depth (sub-Permian rocks) and the location of the margin of underlying granitoids.

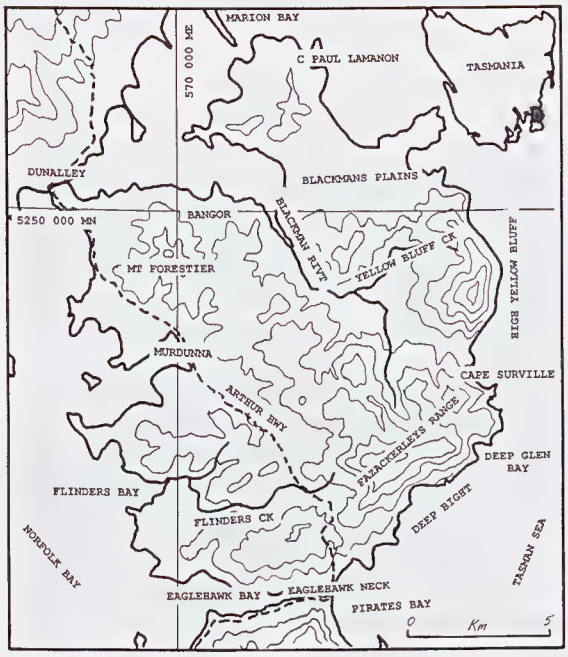


*FIG. 1 — Locality map for the Forestier Peninsula, southern Tasmania.*

## GEOLOGY

The geology of the peninsula was reviewed and inspected while observing gravity traverses. The principal aim, originally, was to note additional dips in sedimentary rocks, to record textural variations in the dolerite and to inspect intrusive margins or contacts which might assist appraisal of the form of the intrusions. The widespread nature of the traverses and the availability of new walking routes, however, showed that some areas had not been traversed for previous maps and that many revisions were necessary. This paper includes a revised version of the regional map of Gulline (1982), based on such new traverses.

A detailed stratigraphy of the area has been provided by Gulline (1984), Gulline & Clarke (1984) and Clarke (1989). This paper considers only those parts of the sequence where new information offers some clarification or variation.

The dominant rock in the region is Jurassic dolerite, which has been intruded, in the form of thick sheets or

wide dykes, into a succession of essentially flat-lying Permian marine rocks and Triassic continental rocks. The terrain is generally fairly rounded, with moderate relief generally decreasing to low relief in the west, and cliffs only occur along the coastal section south of Marion Bay. The Permian rocks were deposited on a basement composed of Devonian granitoids and (?) Ordovician-Devonian slates, phyllites and sandstones of the Mathinna Beds (Gulline & Clarke 1984). Considerable relief, and consequent variation in thickness of the Permian succession, may exist on the basement surface. Banks *et al.* (1989) noted that up to 300 m of relief may exist in the region between Eaglehawk Neck and Deep Glen Bluff. Only the upper parts of the Permian succession are readily accessible; near Cape Surville, Deep Glen Bay and northeastern Bangor, near Cape Paul Lamanon. The lower parts of the Triassic succession are well exposed in the cliffs of High Yellow Bluff but are virtually inaccessible. Triassic exposures elsewhere are very poor and limited.

Significant changes in the regional map by Gulline (1982) were required in the region of Yellow Bluff Creek, Mt Forestier, Macgregor Peak and Machins Hill–Flinders Bay. A large tract of Triassic rocks had been omitted near Yellow Bluff Creek, and the contacts east of Mt Reynolds were shown to be irregular and not a simple faulted boundary. Dolerite talus blankets large parts of the peninsula east of the Arthur Highway, and the material may be mistaken for *in situ* dolerite. The northern and western slopes of Macgregor Peak are draped with this material, and some also occurs west of High Yellow Bluff and around Mt Forestier. Deposits near Mt Forestier tend to be thin, less than 1–2 m thick, but occur on a bedrock of both dolerite and Triassic rocks and conceal important boundaries. One of the best exposures of talus may be seen in a road cutting near the old coal mine lease at 567900E,5247300N, where a mixture of angular and semi-rounded dolerite pieces directly overlies thin coals, mudstones and quartz sandstones.

Gulline (1982) did not subdivide the Permian sequence south of Cape Surville, but a primary division is shown in the revised map (fig. 2). This is based on limited exposures and access from the north side of Fazackerleys Range and Deep Glen Creek and is generally consistent with Gulline & Clarke (1984) and Banks *et al.* (1989). The calcareous units of the central section are not well exposed away from the precipitous cliffs of Deep Bight and the lower slopes of Fazackerleys Range. The subdivision is based on the faunal zonations of Clarke (1989).

Construction of the highway bypass on Hawks Hill has revealed that the boundary between Permian rocks exposed along the coast — near the Tessellated Pavement and Clydes Island (see Banks *et al.* 1989) — and the dolerite of Hawks Hill and Cashs Lookout is a compound, faulted intrusion. The boundary is obscured by sand near Eaglehawk Neck, but road cuts and two small quarries show that coarse-grained dolerite abuts Permian rocks in the lower part of the hill and Triassic rocks near the hill crest. The boundary is, however, intruded by a narrow dyke (5–6 m wide) in most places, although this is offset into the Permian rocks near the road crest. Other, narrower dykes may be found within the main body of dolerite. The larger dyke can be traced as far as Macgregor Link Road (at 575400E, 5241700N). Extensive metamorphic effects may be noted within the upper Permian section on Hawks Hill, which are not consistent with small dykes. The separation of

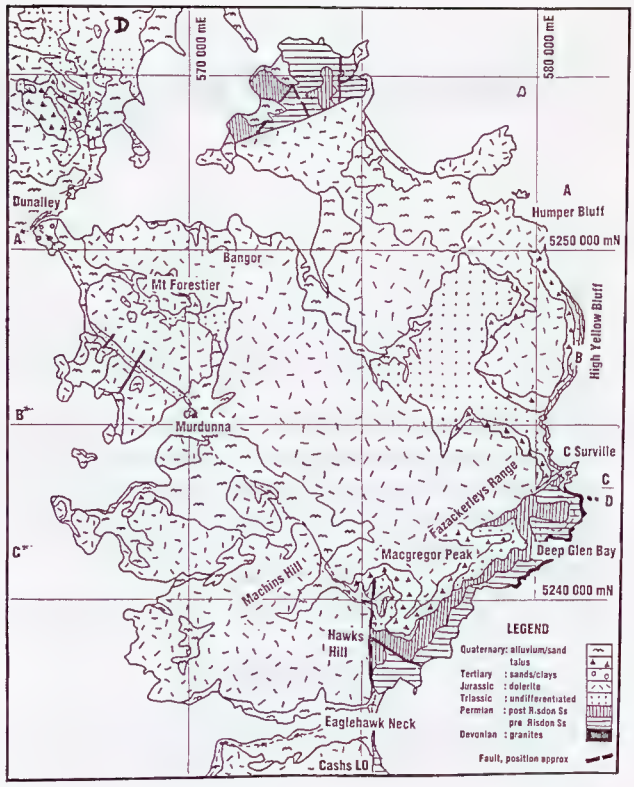


*FIG. 2 — Simplified geology of the Forestier Peninsula. Regional section lines modelled are labelled AA*, BB*, CC*, DD. The asterisk indicates that the origin is off the map (coordinates given in text).*

*The geological base map is derived from Gulline (1982); all revisions are included, as discussed in the text.*

dykes and main contact on the upper part of the hill shows that the main intrusion, which probably occupied a pre-existing fault, was itself intruded, then faulted at least once during the intrusion sequence. It has been faulted again subsequently.

The Permian rocks adjacent to the dolerite dip very steeply west in the central part of Hawks Hill and strike N–S consistent with the orientation of the main fault or intrusive boundary. Parts of the Cainozoic deposits in the eroded fault zone also dip steeply west.

The only other extreme examples of thermal metamorphism may be found at 566600E, 5246850N, where Triassic sandstones have been recrystallised and thermally jointed, and near Cape Paul Lamanon, where Permian rocks have also been deformed (Lewis 1924). The Triassic contact is not well exposed, due to sand cover, but the companion contact near 566750E, 5246120N is generally steeply dipping but very irregular. The small portions of Triassic sequence preserved appear to be near the roof to the intrusion (note the interpreted form at 6 km, in fig. 8). The alteration and folding near Cape Paul Lamanon is consistent with a significant change in the form of intrusion and perhaps faulting concomitant with the intrusion (see also Leaman 1997, Single Hill).

Much of the information about dolerite contacts on Hawks Hill above Eaglehawk Neck has been obscured by an irregular blanket of Tertiary and Recent materials. These were discovered when road excavations were begun for the new highway bypass, and cuttings failed. Cuttings halfway up Hawks Hill display a weathered profile on Permian

rocks, possibly with remnants of a soil, overlain by a weathered boulder bed composed almost entirely of dolerite fragments and dolerite-derived clay. This unit is patchy but overlain by clays, sands and sandy clays (Tertiary?), or by more recent dolerite talus deposits. The more recent, presumed Pleistocene, deposits locally overlie the sandy clays. All materials are unstable and were saturated at the time of road construction. The deposits appear to have been preserved on a hillside shelf, or within a narrow channel, about 100 m above present sea level. The channel has been engraved along the fault-contact zone. Similar materials have been observed at about this level on the slopes along the southern side of Eaglehawk Bay.

Gulline (1982) mapped widespread sand deposits across the peninsula as Pleistocene–Recent in age and windblown in origin. While these conclusions may be generally valid, it should be noted that many such deposits contain a high clay content and may be remnants of Tertiary deposits. The colouring, composition and character of the presumed Tertiary deposits are consistent with materials found widely across southern Tasmania. No fossils have yet been found in these materials on the Forestier Peninsula. The new map (fig. 2) indicates the expanded extent of cover deposits, although not enough is yet known to discriminate properly Recent wind-blown sands and older Tertiary(?) sandy clay deposits.

Patterns in the regional dips recorded from Permian exposures suggest a major structural anomaly. In the northern part of the area south of Marion Bay (Bangor), dips are gentle and consistently to the west (up to 10°). Elsewhere, there is no regular pattern, and most rocks are virtually flat-lying. Around High Yellow Bluff and north of Eaglehawk Neck, dips are subhorizontal and low-amplitude, long-wavelength folds can be found. The dip patterns are not consistent with the extensional fault rotations which might be anticipated, as a reaction to rifting either in the Storm Bay or Tasman Sea regions. Dips are not systematic across the peninsula. A regular dip pattern could be expected, due to rifting or extension, or to regional uplift, which has produced the generally westerly dips across much of southern Tasmania. This structural style is only observed in northern Bangor. These observations suggest, since major uplift reaction from the Tasman Sea separation must have occurred, that isostatic recovery is virtually complete and that equilibrium has been restored, or that responses due to rifting in both east and west have cancelled. The latter possibility seems unlikely since the Storm Bay–Derwent rift axis was clearly active into mid Tertiary time and was clearly an order of magnitude less significant than the Tasman separation. The limited block rotations across the peninsula also imply that Tertiary faulting was relatively minor.

Few faults or intrusive margins exist, or can be mapped, on the peninsula. Several structures display an extended or compound history.

Faults in northern Bangor trend either NE–ENE or a little east or west of north. Faults north of Murdunna trend northeast and the large structure along the eastern side of Hawks Hill trends N–S. High-angle intrusive boundaries, such as those found on north Bangor and near Cape Surville, trend ENE or northeast whilst those faults east of Mt Forestier and Hawks Hill trend N–S. Other contacts, such as those between Murdunna and Dunalley, trend NNW or northwest.

Many smaller faults between Cape Surville and High Yellow Bluff trend approximately E–W. Gross drainage lineaments and fracture patterns indicate a fundamental grain, which includes features which trend northwest and ENE. These orientations are generally consistent with the observations reported for the Tessellated Pavement at Eaglehawk Neck by Banks *et al.* (1989).

Review of the pavement fractures, however, suggests that reported values are either in error or were magnetically defined, since mean orientations are about 15° and 85° with a subset at about 355° rather than the 330-335° and 75° reported. The new observations have been confirmed at the main pavement by Dr M.R. Banks (pers. comm.) with measured means of 13.5°, 89° and 1° respectively. Some minor variations clearly exist within the pavement area, but the two new sets of measurements are concordant and accord with the regional trends more accurately than the published data. The fractures at the pavement display a complex interplay and are dextral (north-trending) and sinistral (east-trending) shears which are neither consistently nor regularly developed through the beds of the formation. Most of the pavement fractures develop upon exposure and weathering of the individual beds and only a small proportion can be considered penetrative or tectonic. There may be no simple relationship between faults, intrusions or obvious joint sets.

## GRAVITY SURVEY

The gravity survey has been undertaken as a new entity independent of the very limited older surveys, in order to remove any risk of dependence on uncertain positions or poor tie links. Most old (pre-1970) tie points cannot be found or occupied. The new survey has been directly linked to Hobart Base (6091.0160, observed gravity 980.44427, at the Engineering Building, University of Tasmania) via a chain of new ties. All intervals in the tie network were multiply observed and drift corrected, and all standard stations have been drift corrected. Elevations were determined barometrically, using the method of Leaman (1984), but many sites were observed either at mean or high-water mark or at survey spot heights. Differential GPS methods have not been used, due to non-availability and lack of secure lock on satellites in this densely forested area. Many elevation estimates are accurate within 0.5 m, while others may contain local errors of up to 2 m. These estimates mean that gravity reduction at a density of 2.67 kg/m$^3$ implies a possible error of up to 0.4 mgal in the Bouguer Correction. A terrain correction has been applied to all stations and was calculated graphically to a radius of 22 km. The correction exceeds 1 mgal in several areas. Some coastal, cliff top stations may be undercompensated due to inadequacies in maps, uncertainties in precise position or inability to define fully terrain close to the observation position.

The likely RMS precision in the Bouguer anomaly, given all observational factors and corrections, is estimated to range between 0.2 and 0.5 mgal and to be less than 0.3 mgal for most stations. A compilation of the Bouguer anomalies is shown in figure 3. Comparison with older data sets has shown that the data of Leaman (1973) and of Zadoroznyj (1975) can be retained, but that most stations acquired by and for Cameron (1967) and Johnson (1972) have been removed from the data base. Undefinable base level shifts were recognised in loop groups, and the average deviation

was 2–4 mgal depending on the particular loop inspected.

Observed Bouguer anomalies present little systematic character, although a distinct gradient bisects the peninsula. Lower values occur to the east. This is very anomalous behaviour, since values should increase as the continental margin is approached, and it implies that a regional mass of low density material occurs at shallow depth beneath the eastern half of the region.

The observed Bouguer anomalies are not particularly valuable, due to the effects of the continental margin, and these have been removed, using the method of Leaman & Richardson (1989) as updated to crustal model MANTLE91. This model is subject to further revision, and refinement will be possible once a detailed survey of the Tasman Peninsula, now in progress, is complete. Residual Bouguer anomalies, derived from the current model, are shown in figure 4 and are not likely to contain any major local distortions. Future changes in MANTLE91 will affect the regional evaluation of southeastern Tasmania.

The residuals retain the substantial W–E gradient, and this reflects gross changes in the upper crust; namely, the presence of a batholith under eastern Tasmania. Parts of the granite complex are exposed along the coast between Cape Surville and Deep Bight. Some major local variations are imposed on the regional gradient. The most important of these are the step effect which strikes N–S across the centre of the peninsula and the sub-circular zone centred near eastern Bangor. Most other changes are minor and swamped by the effect of the underlying batholith, and few can be evaluated by inspection. The residual map defines medium to short-wavelength effects generated in the upper crust, with negligible longer wavelength contributions, due to crustal thickness variations at or near the continental margin. Interpretation of the residual anomalies can be undertaken on the assumption that the mantle model produces locally reliable relationships.

More detailed coverage in the Dunalley and Eaglehawk Neck areas is shown in figures 5 and 6.

The Dunalley survey shows that a distinct negative response curls across the region, which can be directly correlated with exposures of Tertiary sedimentary rocks. The Dunalley canal is excavated within these, and it follows their thickest development.

The Eaglehawk Neck survey does not reveal a comparable negative effect in the region of the neck or tie-bar. A reduced negative response is present, but the entire character of the gravity field is dominated by the effect of the major dolerite–Permian boundary extending N–S across the head of Eaglehawk Bay.

## INTERPRETATION

Six sections have been assessed quantitatively in order to indicate structural style and relationships.

Evaluation has utilised two dimensional methods and a rigorous set of interpretation criteria as defined by Leaman (1994). Use of these criteria leads to realistic and feasible solutions and a denial of invalid solutions. The criteria cannot confirm that any feasible solution found is true, only that it is possible or likely. Rock properties used in calculation have been based on tables published by Leaman (1972) and Leaman & Richardson (1981). Sections are located in figures 2, 5 and 6.

### AA: Bangor east–west (561000/5250000–581000/5251500) Figure 7

This section, of very low relief near sea level, exemplifies many of the geological problems of much of the area and demonstrates the value of a combined geophysical-structural approach. Dolerite is exposed for most of the section, and the remainder is covered by water. Two small segments contain Tertiary materials (near Dunalley). There is no surface suggestion of the nature of structures present.

The model indicates that the dolerite, as a single sheet, was transgressively intruded within the Triassic part of the sequence, and that the whole region has been faulted with a systematic downthrow to the east resulting in westerly dips. This is consistent with a rifted continental margin. Foci for transgression occur at 12 and 17 km and, although the entire character of the intrusion cannot be discerned, it is possible that feeder dykes occur near these locations. In this part of the peninsula, the present gravity survey alone cannot resolve any feeders (if present), and no adequate magnetic data are available which might clarify the issue. Textural variations observed in the exposed dolerite are, however, consistent with an interpretation involving feeders, and data elsewhere are adequate (section DD). The model assumes a uniform thickness of Permian rocks. While there is no reason to expect any major variation in the upper part of the sequence, variations in the lower part cannot be resolved, due to the similarity of granitoid and Permian densities. The model is not affected, with regard to dolerite or fault patterns, even if the Permian section is thinned eastward. The implied displacements and relationships between stratigraphic positions and intrusion transgressions suggests a largely Jurassic (pre or syn intrusion) history on most faults. Demonstrable Tertiary movements are generally of the order of 100 m.

### BB: Dunbabin Point to High Yellow Bluff (561000/5245000–581000/5247000) Figure 8

The general dominance of dolerite near the land surface is again evident. This section may be contrasted with that across Bangor. All faults downthrow to the west, not east, although similar patterns of transgression and thickening are evident within the intrusions. The difference in fault patterns is explained in figure 13 where it is shown that the effect is due to the particular shapes of fault blocks and some changes in trend, within the regional pattern. Faults can be traced or inferred between sections, and displacements are generally less than 150 m. The exceptional structure is west of High Yellow Bluff. The difference in structural pattern (from AA) is consistent with the observed differences in dip patterns between northern Bangor and the region of High Yellow Bluff. The model does not include any large variation in thickness of Permian rocks due to the equivalent and combined effect of Permian rocks and granitoids at the eastern end of the section. The model does show, however, that were an additional dolerite to be present within the Permian sequence — and no such intrusion is known in the region south of Deep Glen Bluff — it would need to be present across the entire section. Further, given the present crustal model (MANTLE91), such a body cannot be inserted

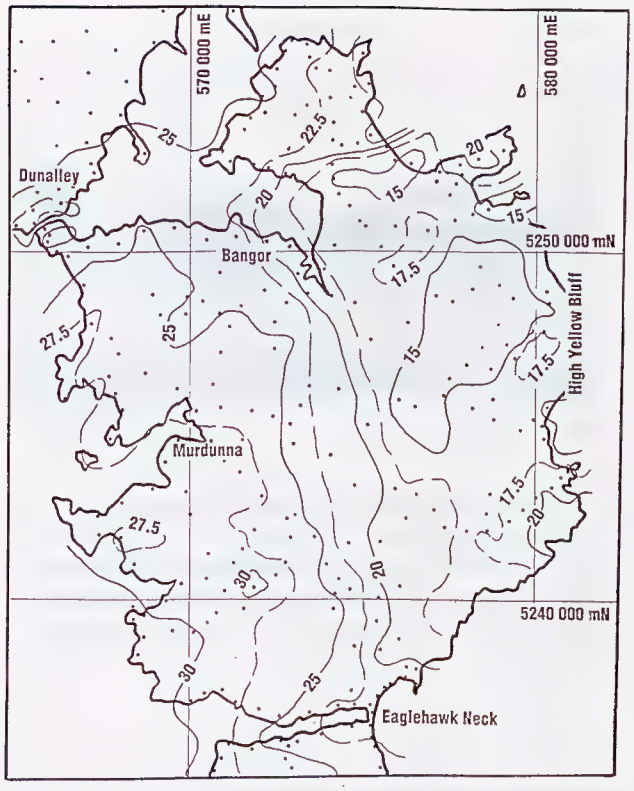


*FIG. 3 — Observed Bouguer anomalies, Forestier Peninsula, based on a reduction density of 2.67 kg/m$^3$ and a datum base value of 980.44427. Station locations are shown as dots and all primary data are stored by Mineral Resources Tasmania. Contour interval 2.5 mgal.*

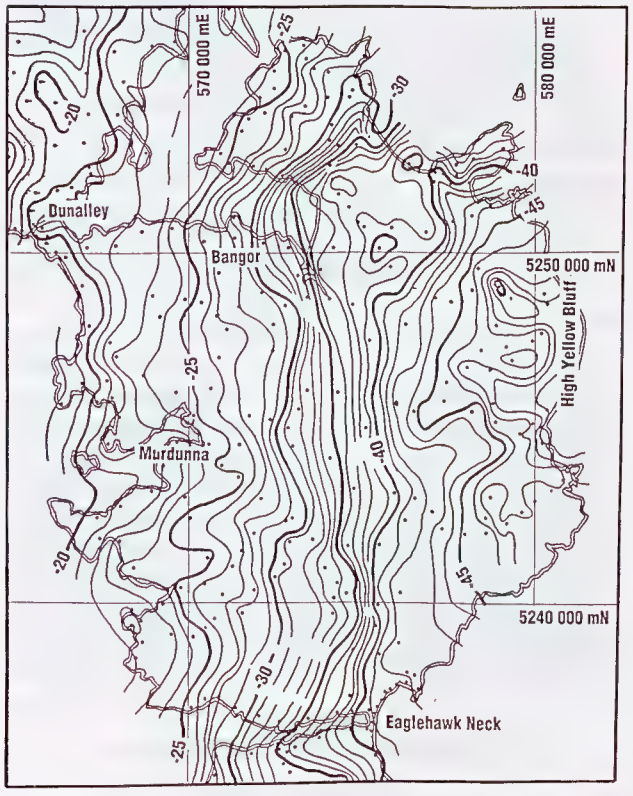


*FIG. 4 — Residual Bouguer anomalies, Forestier Peninsula, after compensation for a first order crust and ocean model. Contour interval 1 mgal.*

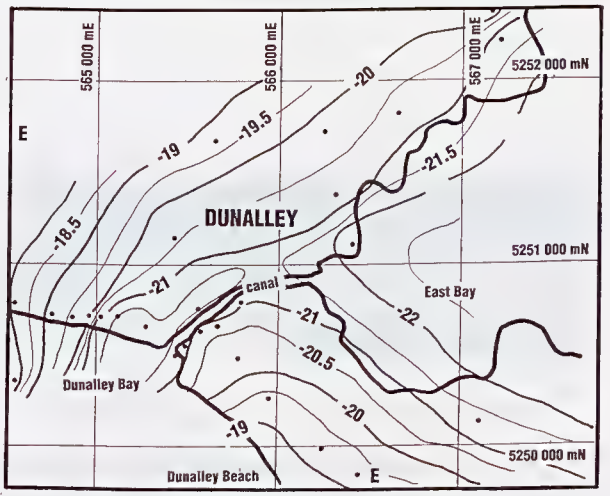


*FIG. 5 — Residual Bouguer anomalies, Dunalley area. Section line EE labelled. Contour interval 0.5 mgal.*

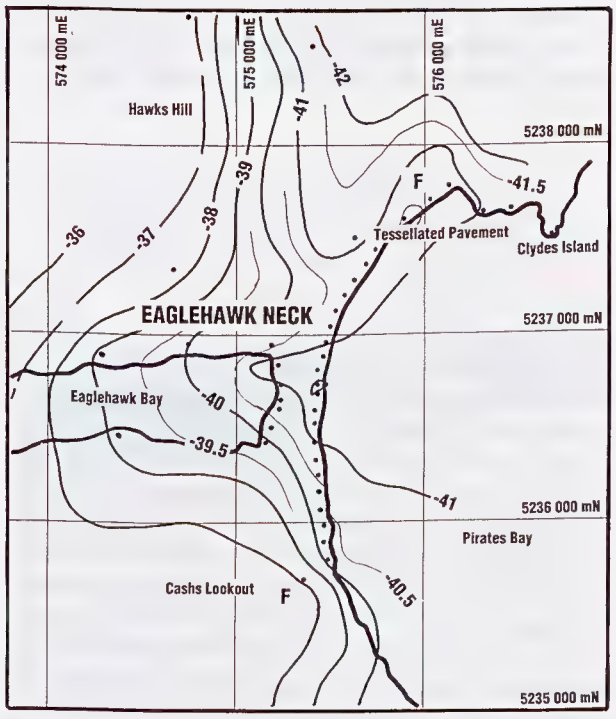


*FIG. 6 — Residual Bouguer anomalies, Eaglehawk Neck area. Section line FF labelled. Contour interval 0.5 mgal.*

into the coastal block. These observations would suggest that the intrusion pattern within the peninsula is relatively simple. The eastern end of the model, however, does not fully explain the observed field. This may indicate deficiencies in the mantle model or, more likely, non-two-dimensional (2D) character, involving structures near sea level at the coast. The effect of the seawater may also not be accurately represented in 2D solutions.

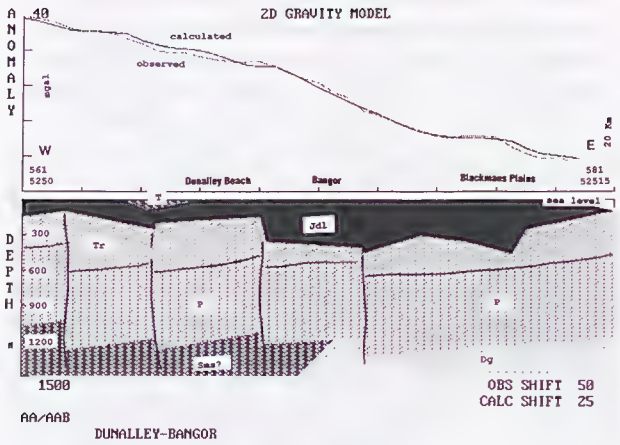


*FIG. 7 — Structural model and interpretation for profile AA. Dunalley–Humper Bluff.*

*Note that the vertical scales provide value ranges (40 mgal and 1500 m) for Bouguer anomalies and depth respectively. The section is 20 km long, and each horizontal axis distance mark has a separation of 2 km. Observed and calculated shift values define the fit of the model, and consistent derivation of differentials provides a test of the veracity of the model (Leaman 1994). Faults are shown vertical since, in the absence of magnetic data, no dip can be assigned reliably.*

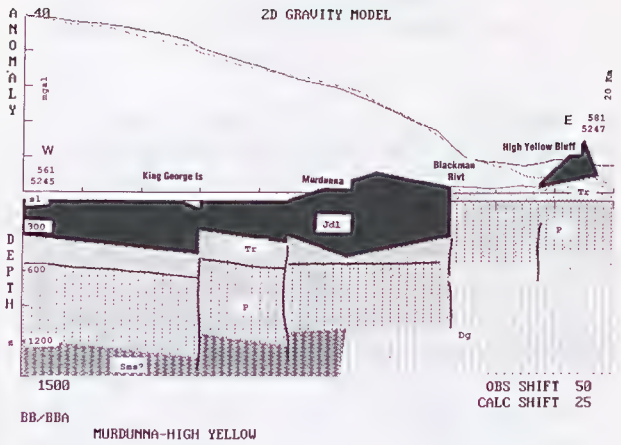


*FIG. 8 — Structural model and interpretation for profile BB. Murdunna–High Yellow Bluff.*

*Fitted anomaly range 40 mgal (vertical axis) and horizontal length of 20 km; subdivided into 2 km intervals. Note that the modelled section represents a subset of a much longer model in order to remove end effects.*

## CC: Flinders to Cape Surville (562000/5241000–582000/5243000) Figure 9

This section provides a different view of the dolerite distribution and shows how large parts of the southern half of the peninsula can carry significant talus deposits with concealed Triassic rocks - the sheet is almost eroded away in several places. A point of transgression has been defined at 12 km from the origin of the section and a small feeding centre is implied. Its position is consistent with similar thickening further north and appears to be associated with the underlying granite margin. The residual values, with inclusion of the coastal dolerite intrusion within the Devonian granitoids, show that no other dolerite is present and that the single intrusion seen penetrating the sub-Permian unconformity is the only major intrusion in the area (see also discussion BB). All faults clearly throw down to the west, in a pattern which is consistent with regional post-Jurassic extension and reactive coastal uplift, due to generation of the Tasman Sea.

## DD: Dunalley North to Cape Surville (568000/5257000–582000/5243000) Figure 10

This section was modelled in order to provide a tieline check on other sections and to confirm the variations in dolerite thickness indicated. The model generally confirms the implications of other sections but illustrates the three-dimensional nature of structures near Cape Surville and the inability of simple methods to define them (compare sections CC, DD). The model also shows that the distinct sub E–W gradient across northern Bangor is due to a dolerite feeder, which is located near the intersection of a large fault extending along Blackman Bay toward Marion Bay and the underlying granite margin.

The interpretation, with thickened dolerite at 9 km, near Blackman Rivulet, provides a verification of the concept presented in line AA and suggests a complex three-dimensional shape for this intrusion. The observed and calculated profiles would also match at Cape Surville, if the dolerite were removed from the model, and the precise positioning of the line, observed data locations, and shape of the cape were included. The model offers a first-order constraint on possibilities and shows that the intrusion exposed in Sisters Bay rises transgressively inland at the coast (also Leaman, 1997). No other intrusions can be present.

## EE: Dunalley (Figure 5)

This detailed model (fig. 11) is essentially an inset for the Bangor model (AA) described above. It offers a complete revision and solution for the canal zone and may be contrasted with the old estimate based only on a short coastal profile (Leaman 1973).

The model shows that the geometry of the Tertiary deposit, in which the canal has been excavated, is related to the underlying faulting and erosion along the structure. Up to 120 m of Tertiary materials are present. The orientation of the modelled fault is not accurately defined but the regional, rather than local, mass balances imply the general attitude shown. A feeder is implied northwest of Dunalley.

## FF: Eaglehawk Neck (Figure 6)

A detailed model for a profile across the Neck is shown in figure 12.

The profile extends across the western side of the Neck, in order to sample the anomaly variation within the hillsides.

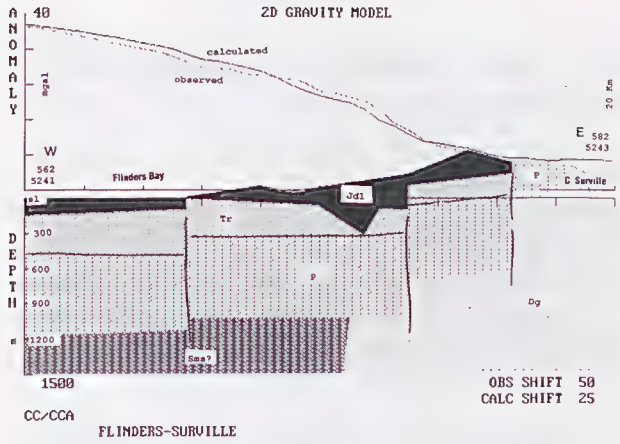


*FIG. 9 — Structural model and interpretation for profile CC. Flinders Bay–Cape Surville.*
*Section length: 20 km marked in 2 km intervals.*

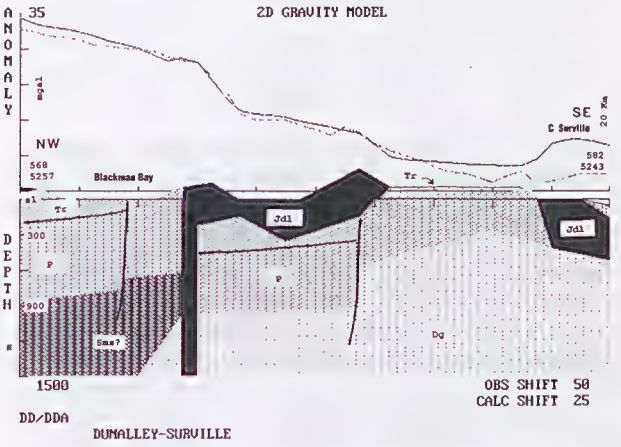


*FIG. 10 — Structural model and interpretation for profile DD. Dunalley north–Cape Surville.*
*Fitted anomaly range 35 mgal (vertical axis) and horizontal length of 20 km marked at 2 km intervals. Note the consistent curve fitting differential of 25 mgal for all regional models with a depth range of 1500 m.*

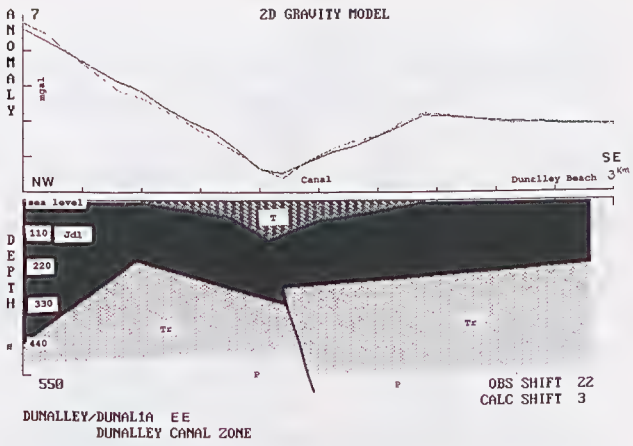


*FIG. 11 — Structural model and interpretation for profile EE, Dunalley area.*
*The fitted anomaly range is 7 mgal and the section length is 3 km marked at 300 m intervals. This model represents a refined version of part of line AA. A fault may be present at about 600 m from the origin and a dolerite feeder immediately west of the origin.*
*This local model requires different curve fitting parameters since the base of the Permian section, and basement detail, is not included in the model.*

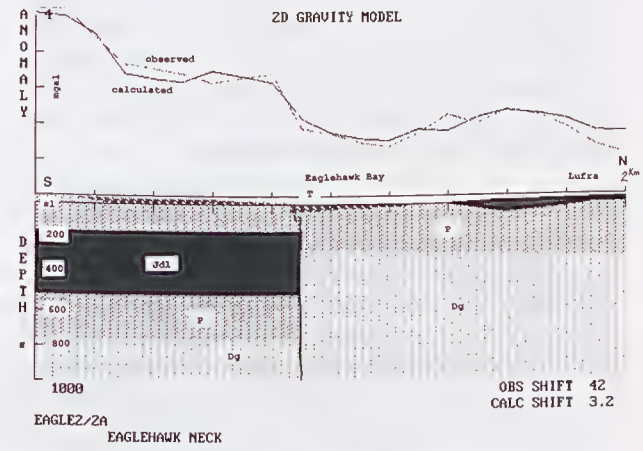


*FIG. 12 — Structural model and interpretation for profile FF, Eaglehawk Neck area.*
*Anomaly range: 4 mgal, depth range: 1000 m. Note the large fault which extends along Eaglehawk Bay and is now covered by Cainozoic deposits which form the tombolo.*

Inspection of Figure 6 shows that a simple or two-dimensional representation of the field is not possible, due to the strong E–W gradient in the region of Hawks Hill and southern Pirates Bay. Although the model is influenced by some lateral effects, the solution does yield credible geological relationships and shows that up to 50 m of Tertiary sediment infilled an eroded channel, etched in a fault zone which extended westward along Eaglehawk Bay. The reduction in anomaly south of Eaglehawk Bay is due to a locally thick blanket of windblown sand (up to 30 m thick).

## CONCLUSIONS

The models show that the area is extensively faulted although post-intrusion displacements are generally less than 100 m. Larger displacements are restricted to structures in the eastern part of the peninsula. The pattern of displacements changes from north to south; mainly down to east in the north and down to west elsewhere. This effect results from the interplay of north and ENE-trending faults and the younger NNW-trending structures. Most post Jurassic faults strike a little west of north, although some large structures trend a little north of east. Many faults have clear relationships with dolerite intrusions, which suggest some concomitant origin but subsequent regional disruption. The largest, established feeder — north of Bangor — is associated with the intersection of several faults (fig. 13). All demonstrable Tertiary deposits are associated with faults which disrupt dolerite intrusions and were clearly eroded. This is most

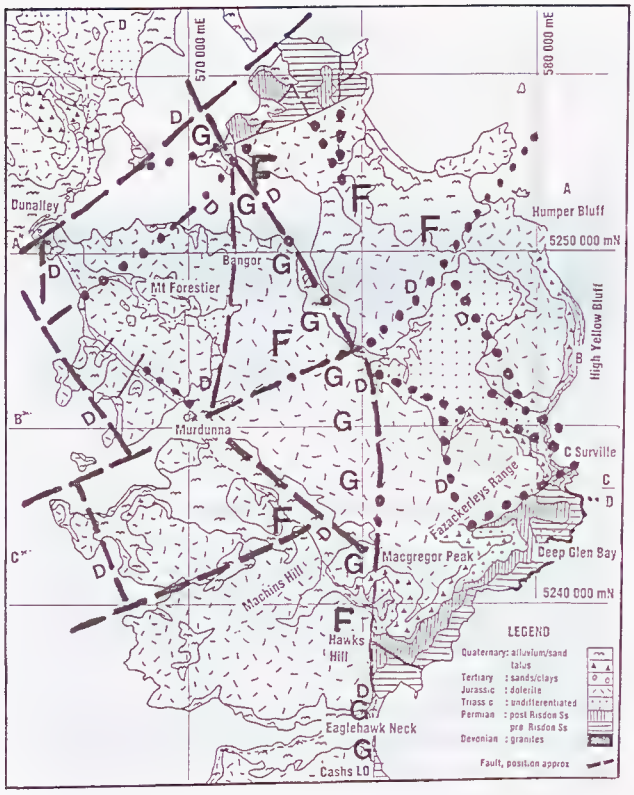


*FIG. 13 — Structural summary. Interpreted faults are indicated by dots (Jurassic or pre-dolerite) or dashes (Jurassic and post-dolerite movement); downthrown side indicated. The approximate position of the underlying granite contact is marked (G) and inferred feeder locations are labelled (F). There is a close relationship between batholith margin and major faults; feeders are locally associated.*

apparent at Dunalley but is also evident at Eaglehawk Neck and at Hawks Hill.

Dolerite feeders, demonstrated and inferred, are related to large faults in the region above the granite margin within the basement complex. The inferred feeder positions, based on texture, thickest development or deepest stratigraphic level, are aligned a little west of north, and most lie near the centre of the peninsula, from near 570000/5255000, along the western side of Blackman Rivulet to Hawks Hill. The arc of feeding structures trends more N–S toward Eaglehawk Neck — as does the granite margin and the fault system above it. Textures and mineralogy of some of the dolerite on Cashs Lookout indicates that this feeding axis extends further south.

## ACKNOWLEDGEMENTS

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(accepted 27 May 1997)

# A LATE MIDDLE CAMBRIAN SHALLOW-WATER TRILOBITE FAUNA FROM THE MT READ VOLCANICS, NORTHWESTERN TASMANIA

by J.B. Jago and A.W. McNeil

(with two text-figures and one plate)

JAGO, J.B. & MCNEILL, A.W., 1997 (31:viii): A late Middle Cambrian shallow-water trilobite fauna from the Mt Read Volcanics, northwestern Tasmania. *Pap. Proc. R. Soc. Tasm.* 131: 85–90. ISSN 0080-4703. Department of Applied Geology, School of Engineering, University of South Australia, The Levels, SA, Australia 5095 (JBJ); Geology Department, University of Tasmania, GPO Box 252-79, Hobart, Tasmania, Australia 7001 (AWM).

Near Middlesex Road, 9 km northeast of the Hellyer mine, northwestern Tasmania, a mineral exploration hole intersects a polymict volcaniclastic conglomerate of the Southwell Subgroup of the Mt Read Volcanics. At depths of 353 m and 364 m, fossiliferous limestone clasts within this conglomerate contain trilobites, including an unassigned agnostoid cephalon, *Amphoton* sp., *Liopeishania* sp., *Menocephalites(?)* sp., *Lisania(?)* sp. and an unassigned member of the Dorypygidae, thus suggesting an age of *Goniagnostus nathorsti* Zone to early *Lejopyge laevigata* Zone (i.e. Late Middle Cambrian) range. This shallow-water fauna is unusual for the Tasmanian Cambrian, in which most faunas are found in deeper water shales and siltstones. The horizon from which the fossils come is stratigraphically close to a rhyolite with a SHRIMP zircon age of 503.2±3.8 Ma; the usefulness of this figure in terms of the Cambrian time-scale is questioned.
**Key Words: Cambrian, trilobites, time-scale, Tasmania.**

## INTRODUCTION

Numerous Middle and Late Cambrian faunas have been described or reported from Tasmania (e.g. Jago & Brown 1989, Laurie *et al.* 1995). Almost all of these faunas are from shale or siltstone sequences, with the only exceptions being a restricted late Middle Cambrian fauna from near Comstock (Jago *et al.* 1972) and a Late Cambrian fauna from the South Coast (Banks & Baillie 1989: 188).

In this paper we report, illustrate and briefly describe a new late Middle Cambrian fauna from within limestone blocks found in an exploration hole (DDH MAC20) near the Hellyer mine, northwestern Tasmania (fig.1). The fossils, all trilobites, were found within two limestone clasts from a mass-flow unit within the Southwell Subgroup of the Mt Read Volcanics.

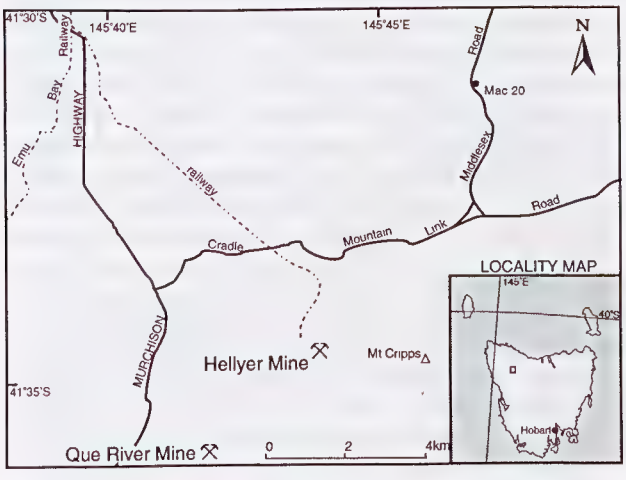


*FIG. 1 — Locality map.*

## STRATIGRAPHY

Corbett (1992) described and summarised the stratigraphy of the Mt Read Volcanics of western Tasmania. The geology of the Hellyer mine area is shown by Vicary & Pemberton (1988). The lithostratigraphy, as outlined by Corbett, is shown in figure 2, with pertinent fossil horizons indicated. The fossils described herein come from the Southwell Subgroup, which is bracketed by the Que River Shale (below) and the Mt Cripps Subgroup.

The Que River Shale contains fossils dated in the range *Euagnostus opimus* Zone to *Ptychagnostus punctuosus* Zone (Jago 1977, Jago & Brown 1989, Laurie *et al.* 1995). The overlying Southwell Subgroup comprises interbedded mass-flow units, tuffaceous sandstone, siltstone, greywacke and pumiceous breccia. Trilobites in limestone clasts in one of the mass-flow units include an unassigned agnostoid cephalon, *Amphoton* sp., *Liopeishania* sp., *Menocephalites(?)* sp., *Lisania*(?) sp., and an unassigned member of the Dorypygidae. This is unusual for Tasmanian Cambrian sequences, in that it represents a shallow-water fauna. It is probably of *Goniagnostus nathorsti* Zone to early *Lejopyge laevigata* Zone, as discussed below.

The Southwell Subgroup is overlain by the Mt Cripps Subgroup, which comprises three informal units along the Cradle Mountain Link Road (Corbett 1992) correlated by White & McPhie (1996: fig. 3) with their newly defined units of the Tyndall Group from the Comstock area north of Queenstown. The basal lensoidal unit (equivalent to Lynchford Member, Comstock Formation, of White & McPhie) comprises siliciclastic conglomerate and siltstone; above this is crystal-rich volcaniclastic sandstone with intercalated fossiliferous mudstone, minor welded pink ignimbrite and minor andesite lavas (equivalent to Mt Julia Member, Comstock Formation, of White & McPhie). The fossils, which belong to at least three separate late Middle Cambrian faunas within the late *Lejopyge laevigata* Zone (Laurie *et al.* 1995), are currently being studied by

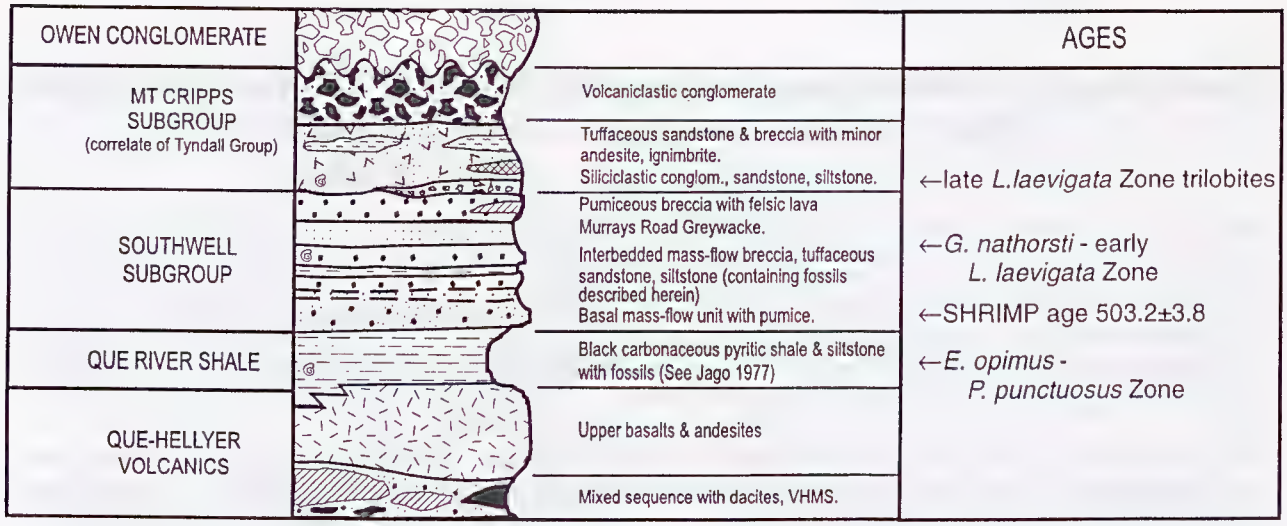
OWEN CONGLOMERATE
MT CRIPPS SUBGROUP
(correlate of Tyndall Group)
SOUTHWELL SUBGROUP
QUE RIVER SHALE
QUE-HELLYER VOLCANICS
Volcaniclastic conglomerate
Tuffaceous sandstone & breccia with minor andesite, ignimbrite.
Siliciclastic conglom., sandstone, siltstone.
Pumiceous breccia with felsic lava
Murrays Road Greywacke.
Interbedded mass-flow breccia, tuffaceous sandstone, siltstone (containing fossils described herein)
Basal mass-flow unit with pumice.
Black carbonaceous pyritic shale & siltstone with fossils (See Jago 1977)
Upper basalts & andesites
Mixed sequence with dacites, VHMS.
AGES
←late L.laevigata Zone trilobites
←G. nathorsti - early L. laevigata Zone
←SHRIMP age 503.2±3.8
←E. opimus - P. punctuosus Zone

*FIG. 2 — Cambrian stratigraphy of the Que River–Hellyer area (modified after Corbett, 1992). The fossils described herein come from limestone clasts within a mass-flow breccia near the middle of the Southwell Subgroup. The SHRIMP age is from Perkins & Walshe (1993) — the significance of this age is discussed in the text.*

C. Bentley (University of South Australia). The top of the Mt Cripps Subgroup comprises volcaniclastic conglomerate and sandstone (Corbett 1992); this is equivalent to the Zig Zag Hill Formation of White & McPhie (1996).

## DDH MAC20

DDH MAC20 was drilled on Middlesex Road (fig.1) with the collar coordinates being AMG 398108.2E, 5402853.3N on the Pearse topographic sheet. DDH MAC20 is an east-dipping hole drilled by Aberfoyle Resources Limited in 1988 to test for massive sulphide-prospective volcanics (equivalent of the Que–Hellyer volcanics) beneath Tertiary basalt, about 9 km northeast of the Hellyer mine. It intersected the following in descending order:

0–51.5 m (45 m true thickness) — Tertiary basalt and sediments
515–184.0 m (101 m) — interbedded polymict volcaniclastic pebble conglomerate to sandstone.
184.0–309.9 m (96 m) — interbedded sandstone, grit and pebble conglomerate with minor volcaniclastic mudstone.
Fault contact
309.9–397.5 m (67 m) — polymict volcaniclastic mudstone, sandstone and conglomerate.

All sedimentary facings are up hole and bedding is moderately southwest-dipping (average 50° dip toward 220° magnetic from core re-orientations in the interval 196–310 m). Limestone clasts have been recovered from the intervals 105–108m and 348.9–368.3 m. Trilobites were found by K.D.Corbett (Department of Mineral Resources, Tasmania) in two limestone clasts at 353 m and 364 m. The latter clast was quite richly fossiliferous; most of the fossils described below come from it. However, as no real difference could be seen in the trilobites from the two clasts they are described below as a single fauna.

The fossil-bearing limestone clasts are in an approximately 16 m thick, normally graded, polymict volcaniclastic cobble conglomerate. Clasts of sub-angular to sub-rounded limestone, angular quartz-feldspar-phyric rhyolite and dacite, ?shard-rich volcaniclastic mudstone, sericitised ?fiamme, grey chert, and black shale are set in a sand-grade matrix composed largely of broken quartz and feldspar crystals and fine quartz-carbonate-sericite altered material of indeterminate origin. The limestone clasts are massive light to dark-grey micrite and dismicrite, with rare patches of secondary quartz and muscovite, scattered biogenic clasts and rare stylolites. This unit is interpreted to be a submarine mass-flow deposit. The limestone clasts were probably partly rounded in a shallow-water environment before incorporation into the flow, while lava clasts may have been derived from hyaloclastic brecciation, and shale, chert, and mudstone may be intraclasts. The source of the limestone may have been a shallow-water carbonate bank fringing a volcano, in much the same way as suggested for shallow-water carbonates of the Comstock Formation near Queenstown (see White & McPhie 1998: fig. 7a).

The interbedded volcaniclastic mudstones, sandstones and conglomerates, polymict conglomerates, etc., intersected below 51.5 m in DDH MAC20, are lithological correlates of the Southwell Subgroup, as defined by Pemberton *et al.* (1991) and Corbett (1992), which outcrops both to the southwest and northeast of DDH MAC20 and is best exposed on the Cradle Mountain Link Road to the southwest (fig. 1). The upper part of the hole correlates with the upper pumiceous breccia and Murrays Road Greywacke (about 300 m thick on the Cradle Mountain Link Road). The fossiliferous limestone-bearing unit correlates with the lower interbedded mass-flow breccia and tuffaceous sandstone and siltstone unit (fig. 2). This correlation implies that the rocks containing the limestone clasts are younger than the Que River Shale (late Middle Cambrian, Undillan; Gee *et al.* 1970, Jago 1977) and older than the fossiliferous siltstone and shale of the Mt Cripps Subgroup (Tyndall Group correlate) on the Cradle Mountain Link Road (very late Middle Cambrian, *Lejopyge laevigata II* Zone–passage zone; Jago in Pemberton *et al.* 1991). No source of the limestone clasts has been identified.

## BIOSTRATIGRAPHIC AGE OF FAUNA

The fragmentary nature of the trilobites does not allow an exact biostratigraphic age to be determined. The agnostoid cephalon described herein is of little value in this regard. The majority of the species assigned by Zhang & Jell (1987) to *Menocephalites* are found in the *Taitzua–Poshania* Zone, which these authors correlated within the *Goniagnostus nathorsti* Zone of northern Australia, although Shergold *et al.* (1990) suggested correlation with the lower part of the *Lejopyge laevigata* Zone. *Amphoton* is well known in the late Middle Cambrian of China, Korea, Antarctica, Australia and New Zealand. *Amphoton* sp., as described herein, is probably closest to *A. spinigerum* Whitehouse of Queensland. Öpik (1982) suggested that *A. spinigerum* is found in the *G. nathorsti* Zone. *Lisania* occurs in the late Middle Cambrian Zhangxian Stage of North China (Zhang & Jell 1987). *Liopeishania* is the nominate genus of the *Liopeishania* Zone, which Zhang & Jell (1987) correlated with the *Lejopyge laevigata* Zone of Australia; Shergold *et al.* (1990) suggested correlation with the upper part of the *L. laevigata* Zone. Palmer & Gatehouse (1972) described *Liopeishania spannensis* from the late Middle Cambrian *Schopfaspis granulosus* faunule of Antarctica. Cooper & Shergold (1991) included this within their Fauna 3, which they considered to be of Floran to Undillan age.

In summary, generic correlation with elsewhere in Australia and China plus the stratigraphic position of the unit suggest an age in the *Goniagnostus nathorsti* Zone to early *Lejopyge laevigata* Zone interval.

## RELEVANCE TO CAMBRIAN TIME-SCALE

The Cambrian time-scale is in a state of flux (Young & Laurie 1996), due to a lack of reliable geochronologic dates which can be tied in with the various biostratigraphic scales. It is worth noting the date given for the Middle–Late Cambrian boundary in two recent papers. Young & Laurie (1996) suggested an age of 498 Ma, whereas Gradstein & Ogg (1996), following Tucker & McKerrow (1995), suggested a figure of 505 Ma. This may not seem particularly significant, but it is of some importance when it is realised that, in the tables given in Young & Laurie (1996), there are 29 trilobite zones (mainly agnostoid-based) from 506 Ma (base of the Late Templetonian–Floran) to 491 Ma (top of Payntonian), i.e. the average time span for a trilobite zone over this interval is about 520 000 years using the Young & Laurie time-scale.

Perkins & Walshe (1993) dated a rhyolite lava (their sample 91-278) from what they termed (p.1180) "the Upper Rhyolite sequence north of the Cradle Mountain link road" as having a SHRIMP zircon age of 503.2 ± 3.8 Ma. Although no exact geographic or stratigraphic details were given by Perkins & Walshe, on their figure 2 they indicated that sample 91-278 came from near the base of the Southwell Subgroup, i.e. at a slightly stratigraphically lower level than the trilobites described herein. However, given that the trilobites come from allochthonous clasts of limestone, there is doubt as to the original stratigraphic relationship between them and sample 91-278.

If the SHRIMP date of 503.2 ± 3.8 Ma is accepted as correct, then, given its stratigraphic position (fig. 2), it would suggest that the Young & Laurie (1996) figure of 498 Ma is more likely to be correct than 505 Ma for the Middle–Late Cambrian boundary. However, the error given by Perkins & Walshe was a 1σ error, which only encompassed a 67% confidence limit, whereas the current convention is to give a 2σ error, which encompasses about a 95% confidence limit. This would make the Perkins & Walshe date 503.2 ± 7.6 Ma, a more realistic figure, which would allow the possibility of 505 Ma as the Middle–Late Cambrian boundary date. In either case, particularly the more realistic one, it is evident that the error bar from the geochronologic work covers quite a number of trilobite zones. Extremely precise geochronological dates with good biostratigraphic links in the Middle and Late Cambrian will be required to make significant alterations to the Cambrian time-scale, as well as to the average time-span suggested above for the Middle and Late Cambrian trilobite zones.

## SYSTEMATIC PALAEONTOLOGY

The specimens figured herein were extracted from the limestone pebbles by first heating the pebbles to about 800°C for one hour and then quenching them in water. In common with most other Tasmanian Cambrian faunas, the fossils from these pebbles show the effects of tectonic distortion. All figured specimens were photographed after being whitened with magnesium oxide. All catalogue numbers refer to the collections of the Geology Department, University of Tasmania.

### Agnostoid gen et sp. indet
### Pl. 1M

Remarks

One poorly preserved agnostoid cephalon (UTGD125300) is available. It may belong in *Peronopsis* or allied genus.

### Family DORYPYGIDAE Kobayashi, 1935
### Dorypygidae gen et sp. indet
### Pl. 1G, H, I

Material

Two partial cranidia and three partial pygidia (UTGD125305–125308).

Remarks

The fragmentary nature of the material prevents generic assignment.

### Family DOLICHOMETOPIDAE Walcott, 1916
### Genus AMPHOTON Lorenz, 1906

Type species

*Amphoton steinmanni* Lorenz, 1906 (= *Dolichometopus deois* Walcott, 1905).

Diagnosis

See Zhang & Jell (1987): 62.

### *Amphoton* sp.
Pl. 1A, B, D

Material
Two partial cranidia, a pygidium and a hypostome (UTGD125312–125315).

Description
Surface ornament absent. Strongly convex, parallel-sided glabella extends to anterior border. Moderately deep axial furrows. Glabella anterior is broadly rounded. Four pairs of lateral glabella furrows; 1 p deep laterally, bifurcating adaxially with the posterior branch extending almost to the occipital furrow; 2p well developed and directed slightly to the posterior; 3p and 4p furrows shallow, directed slightly to the anterior. Wide deep occipital furrow, occipital ring near the base of what appears to be a strong spine. Anterior border furrow shallow; short anterior border appears to widen abaxially. Arcuate palpebral lobes close to the glabella extending from just forward of the occipital ring to between the 2p and 3p furrows where they appear to meet the axial furrow. Palpebral areas of fixigenae flat; wide palpebral furrows; strap-like posterolateral limbs; long, shallow, posterior border furrow. Pygidium (UTGD125314, pl.1D) with almost effaced axis of two axial rings and a terminus. Pleural areas almost totally effaced except for one pleural furrow. Shallow, narrow border furrow; wide flat border.

Discussion
The specimens described herein are probably closest to *A. spinigerum* Whitehouse by virtue of the shape of the glabella and palpebral lobes. However, the palpebral lobes of *A. spinigerum* extend further forwards, and its 1p furrows do not bifurcate.

## Family SOLENOPLEURIDAE Angelin, 1854
## Genus MENOCEPHALITES Kobayashi, 1935

Type species
*Menocephalus acanthus* Walcott, 1913, p.173, pl.16, figs 4, 4a, 4b.

### *Menocephalites* (?) sp.
Pl. 1C, E, F

Material
Three partial cranidia (UTGD125309–125311).

Remarks
These cranidia have a strongly convex glabella which extends to the anterior border, a well-developed occipital furrow and deep axial furrows. The glabella tapers forwards to a broadly rounded anterior. The fixigenae are strongly convex. Occipital spines absent. They may belong to *Menocephalites* as diagnosed by Zhang & Jell (1987: 102). They are similar to the specimens described by Cooper *et al.* (1996) from northern Victoria Land, Antarctica, as *Menocephalites(?)* sp., except that the Antarctic specimens have a well-developed occipital spine.

The 1p furrows of most species of *Menocephalites* are shallow, but distinct; there is no sign of the 1p furrows on the specimens figured here. There is no sign of the tuberculate ornamentation present in most species of *Menocephalites.*

## Family ASAPHISCIDAE
## Genus LIOPEISHANIA Chang, 1963

Type species
*Psilaspis? convexus* Endo in Endo & Resser, 1937, p. 350, pl. 59, figs 1-4.

Remarks
Four species of *Liopeishania* have been described. Three of these are from the late Middle Cambrian of China, i.e. *L. convexus* (Endo), *L. lubrica* (Chang) and *L. leura* Yang. Palmer & Gatehouse (1972) described *L. spannensis* from the late Middle Cambrian of Antarctica.

### *Liopeishania* sp.
Pl. 1L, N, O

Material
Five distorted partial cranidia, including UTGD125301–125304.

Remarks
These specimens fit the diagnosis of *Liopeishania* as given by Palmer & Gatehouse (1972: 22). The glabella is outlined by shallow axial furrows which become even shallower forwards; the lateral glabella furrows are completely effaced. The glabella stops just short of the narrow shallow anterior border furrow. The absence of eye ridges differentiates it from *L. spannensis.* The border furrow is not as wide as that of *L. convexa.* However, the limited number and the incomplete and poorly preserved nature of the specimens do not allow either a detailed comparison or a definite species assignment.

## Family LISANIIDAE Chang, 1983
## Genus LISANIA Walcott, 1911

Type species
*Anomocarella(?) bura* Walcott, 1905.

Diagnosis
See Zhang & Jell (1987): 134.

### *Lisania(?)* sp.
Pl. 1J, K

Material
Three fragmentary cranidia (UTGD125316–125318) are tentatively placed in *Lisania.* The anterior of the cranidium, the path of the facial sutures and the posterolateral limbs cannot be seen. However, the largely effaced glabella which tapers slightly forwards, the position of the anterior end of the palpebral lobe close to the glabella, the shallow axial furrows, and the presence of a low occipital node resemble *Lisania.*

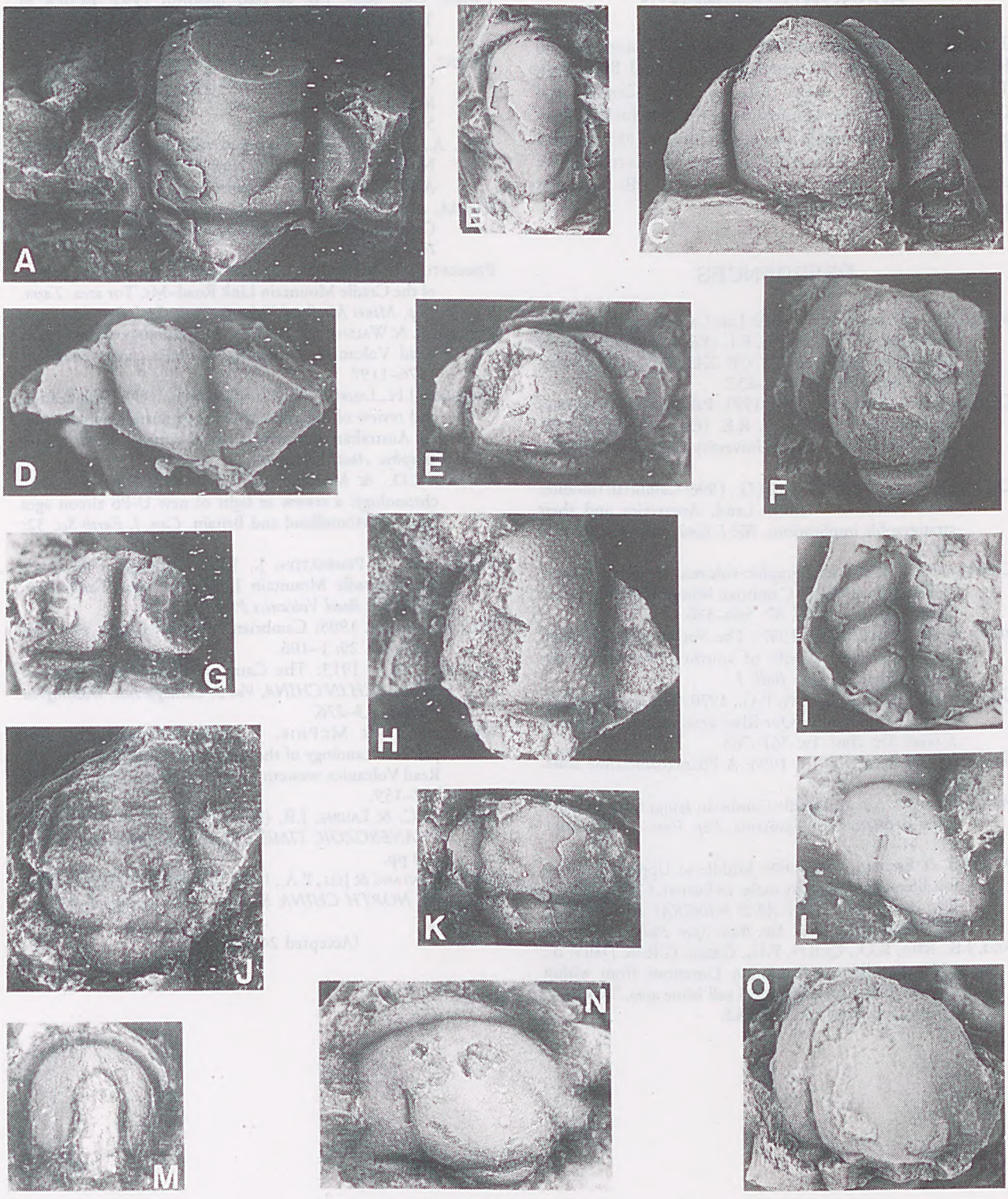


PLATE 1

*(A, B, D)* Amphoton *sp. (A) UTGD125312 partial cranidium, ×5; (B) UTGD125313 partial cranidium, ×7; (D) UTGD125314 partial pygidium, ×8.*

*(C, E, F)* Menocephalites(?) *sp., partial cranidia. (C) UTGD125309, ×5; (E) UTGD125311, ×5; (F) UTGD125310, ×4.*

*(G, H, I) Dorypygidae, gen et sp. indet. (G) UTGD125306, partial cranidium, ×4; (H) UTGD125305, partial cranidium, ×5; (I) UTGD125307, latex cast of partial pygidium, ×7.*

*(J, K)* Lisania(?) *sp., (J) UTGD125316; (K) UTGD125317, partial cranidia, both ×5.*

*(L, N, O)* Liopeishania *sp. (L) UTGD125302, latex cast of partial cranidium, ×5; (N) UTGD125301, cranidium, ×5; (O) UTGD125303 partial cranidium, ×5.*

*(M) Agnostoid gen. et sp. indet., UTGD125300, cephalon, ×11.*

## ACKNOWLEDGEMENTS

The limestone clasts containing fossils were first recognised by Dr K.D. Corbett (Department of Mineral Resources, Tasmania). Dr J.A. Cooper (Department of Geology and Geophysics, University of Adelaide) is thanked for advice on geochronology. Aberfoyle Resources Limited are thanked for granting access to the core. Two anonymous referees are thanked for their constructive comments. J.B. Jago was supported by an ARC grant.

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